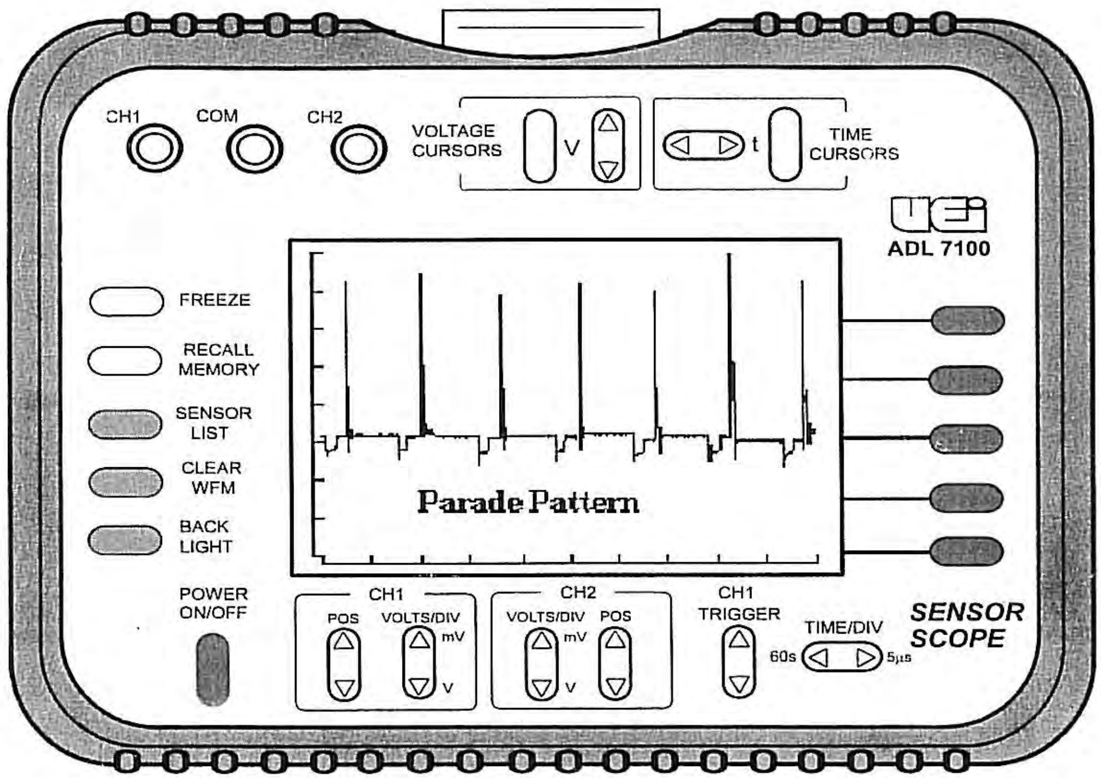
ADL 7100 USER'S GUIDE FOR ENGINE SERVICE TECHNICIANS



Safety Warnings & Cautions - Read this user's guide completely before using the lab scope.

1. Unless instructed otherwise, the parking brake should be applied and the gear selector in neutral (*standard transmission*) or park (*automatic*) and the drive wheels blocked before performing a test with the engine running. The ignition or fuel system must be disabled when performing starting system tests.
2. Always wear safety goggles when working near batteries. If considerable time is spent handling/servicing batteries, wear protective clothing. Avoid making an accidental connection between battery terminals with tools, jumper leads, etc. Use a suitable battery carrier when transporting batteries.
3. Keep yourself, clothing and test equipment clear of all moving or hot engine parts.
4. Do not smoke or allow open flames or sparks in the work area. Gasoline fumes and gases produced by batteries are highly explosive.
5. Exhaust gas contains deadly poison. When testing a vehicle with the engine running, test in a well-ventilated area or route exhaust gas outside.
6. On marine applications with inboard or inboard/outboard engines, make sure work area is well ventilated. Operate bilge blower for at least four minutes before starting engine or making test lead connections.
7. Be sure ignition is in the OFF position, headlights and other accessories are off, and doors are closed before disconnecting battery cables. This also helps to prevent damage to on-board computer systems.
8. Always disconnect the ground connections on all batteries before servicing the electrical system. Be sure all test leads are connected as instructed before proceeding with a test.

ADL 7100 USER'S GUIDE FOR AUTOMOTIVE SERVICE TECHNICIANS

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Introduction to the Oscilloscope

This guide should be used to get you started in troubleshooting electrical problems using the ADL 7100. Your real learning can best be accomplished through experience. As you become more proficient in using the lab scope to troubleshoot, you will learn very quickly how certain electrical symptoms can relate to various driveability problems

Automotive electrical problems can be divided into several categories, that we will discuss later in this guide. Depending on the system in the vehicle causing the trouble, the real problem may exist in one system, while the symptoms you are testing appear in another. An oscilloscope can help you to isolate the real cause of a particular problem.

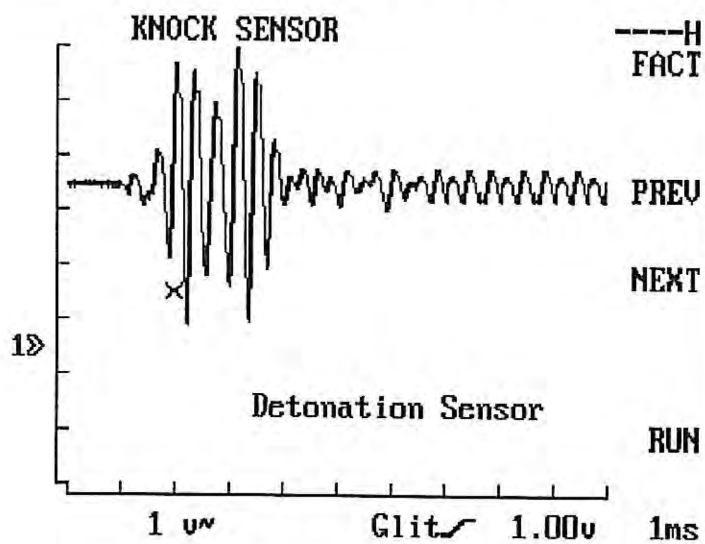
Oscilloscopes should be thought of as any other tool in the technician's or mechanic's tool box - just like another wrench or scan tool or multimeter. It will not solve all of your problems. It was only designed to give you some information about electrical activity (*or lack of*) occurring in components, sensors and wires of the vehicle's electronics.

For many years oscilloscopes have been used in the world of electronics. At first, they were (*and still are*) used in the design phase of many electronic systems. Then, their usefulness became even more important for diagnosing and repairing electronic devices (*especially out in the field, far from the resources of factories and personnel*). Once the oscilloscopes became smaller, lighter, battery powered and more portable, almost every electronic technician was required to have a scope as an essential diagnostic tool.

Electronic technicians realized early on, that trying to troubleshoot many electronic systems without oscilloscopes was equivalent to trying to drive a car with your eyes covered. Your other senses could detect the fact that events were occurring, however, it is difficult to determine exactly what those events are. Oscilloscopes have been used by technicians to repair many types of electronic devices like TV's, VCR's, computers and copiers.

The oscilloscope is not limited to the electronics world. With the appropriate transducer, an oscilloscope can measure almost any kind of physical phenomena.

A transducer is a device that produces electrical energy in response to some kind of physical energy. As an example, a detonation or "knock" sensor on an engine is a transducer. A typical knock sensor contains a piezoelectric crystal that produces an electrical signal when it is subjected to mechanical stress, i.e. - the engine knocking (*shown below*).



For years "Ignition Scopes" were used to display secondary ignition patterns from conventional ignition systems. You can still view secondary ignition patterns on today's oscilloscopes. However, it is extremely important to realize that there are many other patterns, signals and sensor outputs that need to be checked on the vehicles being built today. The only way to determine if many of these circuits are performing properly is to use a lab scope.

As you progress through this guide, the benefits of using an oscilloscope will become very obvious. The job of troubleshooting difficult electrical problems will become easier, as you become more familiar with the functions and features incorporated into the ADL 7100.

Chapter 1 - Fundamentals of Automotive Electronics

Troubleshooting electrical systems uses the same skills you have already developed as an automotive technician. It is important to use a logical process of deductive reasoning to solve any problem you might encounter in a vehicle. This process is important, since you can not see inside or listen to electrical components to tell if they are functioning properly, (*like you can with mechanical devices*). Thinking through the process in a logical and organized way should help you determine the source of the problem the first time.

There are typically four basic elements that make up a complete electric circuit. They are the energy source, the conductor or circuit wiring, the circuit load or device and the control (*which, can be optional*). In a complete circuit, all of the current that leaves a power source also returns back to the power source.

Current represents the movement of electrons through an electric circuit. The amount of electrical current flow is measured in Amperes (*usually shortened to Amps*). The symbol for Amperes or Amps is the letter "I".

Many vehicle electronic circuits use only milliamps of current to operate. (*A milli-Amp is 1/1000th of an Ampere.*) The symbol for milliamp is "mA"

Another term that is important to understand is Resistance, which is the opposition or restriction to current flow in a circuit. Electrical resistance is measured in terms of "Ohms". Every part of any electrical circuit has resistance, including the wiring to and from that circuit. Lights, relays and electronic devices in a circuit are often referred to as the "Load" and all have some resistance, called the "Load Resistance".

Resistance in a wire can be affected by a number of things including the wire length and diameter, wire type, the temperature and condition of the wire. You should always check the condition of the circuit wiring before replacing any suspected bad components.

The reason that current flows from the battery, through the circuit, and back is because of a force called the "Electromotive Force", or "emf".

The total amount of electromotive force, or difference in potential, that is present is measured in terms of "Volts" or "Voltage" using the symbol "E". A typical vehicle battery has a difference in potential electromotive force between the positive and negative terminals of just over twelve volts. A battery provides this voltage by a chemical reaction that takes place inside the battery. In contrast, an alternator needs mechanical movement of a wire through a magnetic field in order to produce this voltage.

A vehicle battery supplies what is called "**D**irect **C**urrent" or "**DC**", and current flows in one direction. Conventional theory - used by the automotive industry - says current flows from the positive terminal, through the circuit, to the negative terminal.

On the other hand, there is "**A**lternating **C**urrent" or "**AC**" which first flows in one direction, then "alternates" and flows in the opposite direction. This happens continuously many times per second. The electricity supplied to your home from the electric company is "AC", (*it alternates at a rate of sixty times per second or 60 Hz*).

In vehicles, the alternator supplies AC or alternating current which is converted or rectified to DC or direct current that is supplied by the battery for use in most of the electrical circuits in the vehicle.

A very important physical law governing electricity is called Ohm's Law. This law states that Voltage, Current and Resistance are all related to each other. According to Ohm's Law, one volt in a circuit with a resistance of one ohm will cause a current flow of one ampere.

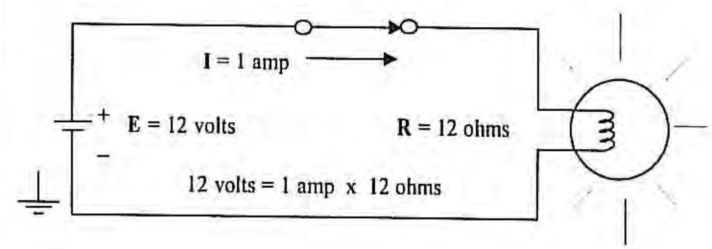


Figure 1-A: Typical Basic Circuit

Voltage, current, and resistance in any electrical circuit can be calculated by using Ohm's Law, which states "the voltage in a circuit is equal to the current multiplied by the resistance". If any two values in the formula are known, the third can be determined.

Ohm's Law States:

Amperes = Volts ÷ Ohms

Ohms = Volts ÷ Amperes

Volts = Amperes x Ohms

According to Ohm's Law, if the resistance in a circuit stays constant, a change in voltage will cause a similar change in current. If the voltage stays constant, a change in resistance will cause an opposite change in current.

Below is a simple example which illustrates how to use Ohm's law to solve for an unknown voltage, current or resistance in a simple circuit.

To solve for E:	To solve for I:	To solve for R:
$E = I \times R$	$I = \frac{E}{R}$	$R = \frac{E}{I}$
$E = 1\ \text{amp} \times 12\ \Omega$	$I = \frac{12\ \text{volts}}{12\ \Omega}$	$R = \frac{12\ \text{volts}}{1\ \text{amp}}$
$E = 12$ volts	$I = 1$ amp	$R = 12\ \Omega$

*(**Note:** In the above example "—" means "divide by" and "x' means "multiply by".)*

Ohm's Law explains the relationship between voltage, current and resistance. The next graphic shows you how to quickly solve for the unknown value. Put your finger over the value you want to find, then multiply the remaining values if they are side-by-side or divide them if one is over the other.

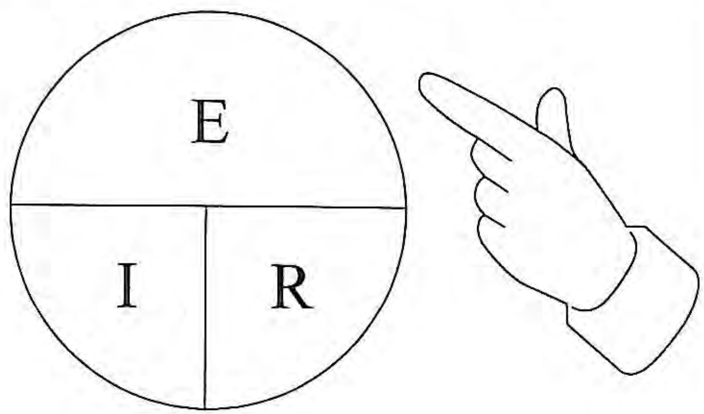


Figure 1-B: Ohm's Law Circle

In vehicles there are three types of automotive circuits that exist. The circuits are Series, Parallel and Series-Parallel circuits.

In a Series circuit - there is a power source, wiring to and from the power source, one or more loads with a single current path and an optional control.

The current flowing in a series circuit is the same at any point in the circuit. Let's look at a simple series circuit:

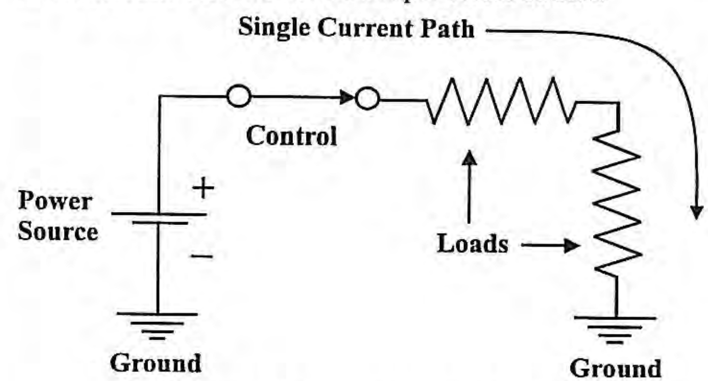


Figure 1-C: Simple Series Circuit

In a Parallel circuit - there is a power source, wiring to and from the power source, more than one load (*connected to produce multiple current paths*) and an optional control.

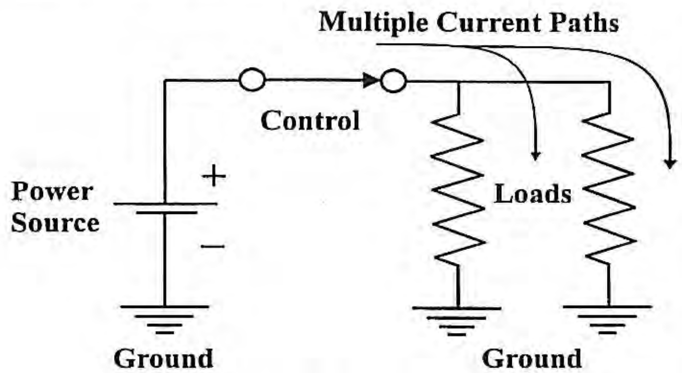


Figure 1-D: Simple Parallel Circuit

The current flowing in a parallel circuit divides among the separate branches. The total circuit current is equal to the sum of the individual branches. The current through each branch is determined by the load resistance in that branch.

In a Series-Parallel circuit - there is a power source, wiring to and from the power source, more than two loads connected (*in series and parallel*) to produce multiple current paths and an optional control. A Series-Parallel circuit can be a series circuit wired with two or more loads in parallel. It can also be a parallel circuit with the loads of one or more branches wired in series.

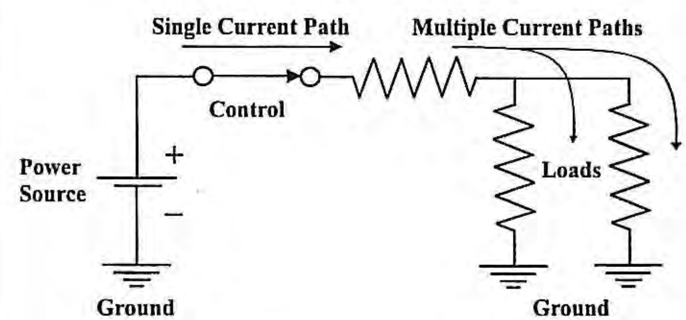


Figure 1-E: Simple Series-Parallel Circuit

There are two very common types of problems or faults that can exist in a circuit. They are known as an "Open Circuit", commonly called an "Open" and a "Short Circuit", commonly called a "Short".

A short circuit can exist between components, or directly to ground, causing a "Grounded Circuit". An open circuit has a complete break in the current path at some point causing one or more circuit loads or devices to not work.

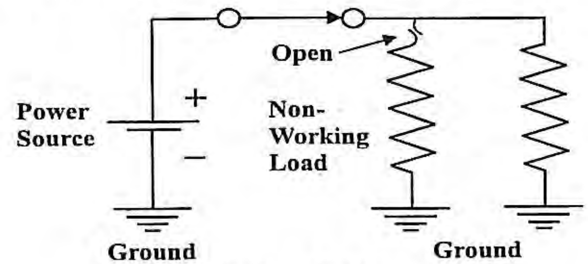


Figure 1-F: Simple Open Circuit

Since electricity will always take the path of least resistance, a short across a load will by-pass that load either through a lower resistance or directly to ground.

This will cause the shorted load and other components in the same circuit to malfunction or not work at all.

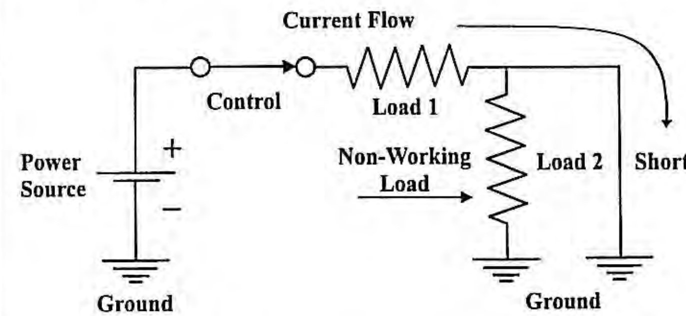


Figure 1-G: Simple Short Circuit

*(**Note:** It is important to realize that the loads or components may be operational, yet not working properly because of the short in the system.)*

Chapter 2 - Comparing DMM's, Scan Tools & Scopes

All of these tools have unique capabilities, and today's vehicles demand that technicians are able to use all three tools to correctly diagnose many of the problems that exist. Oscilloscopes alone can not replace voltmeters or scan tools. By the same token, voltmeters or scan tools can not replace oscilloscopes. Take for instance, a wheel speed sensor - a customer with anti-lock brakes comes into your shop and complains that the brakes on his car are sometimes erratic. You road test his vehicle and confirm the problem. During the road test you notice that the ABS light does not come on. When you get back to the shop, you plug in your scan tool and find no trouble codes. Well you still have your voltmeter - you follow the manufacturer's instructions and you look at the output voltage from each of the wheel speed sensors. They all appear to be in tolerance, and the manufacturer's fault tree informs you the next step is to replace the ABS computer. Unfortunately, the ABS computer on this vehicle is embedded in the master cylinder, so you must replace everything. The worst part is after you complete all of the work the problem still exists.

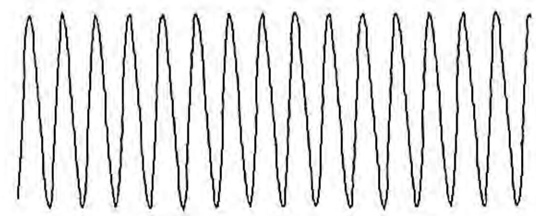


Figure 2-A: Normal ABS Signal

Most of the signal shown in figure 2-A is visible to voltmeters, scan tools and scopes

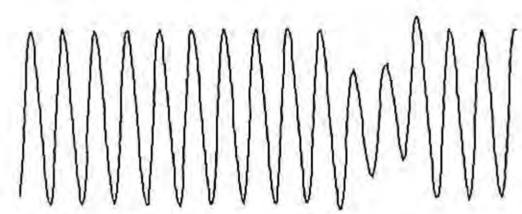


Figure 2-B: Faulty ABS Signal

However, the faults shown in figure 2-B are not visible to voltmeters and scan tools. They are only visible to scopes.

If you had a scope, you could look at the output signal from each of the wheel speed sensors. From this you would have discovered that the right rear wheel speed sensor had some very fast aberrations that caused the ABS computer to act strange. You replace the right rear wheel speed sensor and cure the problem. The scan tool missed this problem because no trouble codes were set and the computer communications bus was too slow to pick up the spikes. The voltmeter missed this problem because it averaged the sensor signals and could not see the fast aberrations.

Scan tools and DMMs sample very slow when compared to scopes. Scan tools are limited to sampling less than 100 times per second and many only sample at 10 times per second. The fastest handheld digital multimeters only sample at 1,000 times per a second and digital multimeters also average the value of the signal you are viewing. Digital oscilloscopes sample at more than 1,000,000 times per second.

This means digital oscilloscopes are typically more than 100,000 times faster than scan tools and more than 1,000 times faster than DMMs.

There are many examples of vehicle signals that voltmeters and scan tools are unable to see. There are many vehicle problems that can occur that really require a scope to diagnose accurately. Trying to solve these problems with just voltmeters and scan tools would be like trying to diagnose a problem wearing a blindfold, you simply could not see.

Voltmeters average many samples together to display a composite value of the signal, and on AC signals they typically display what is referred to as the **RMS** (<u>R</u>oot <u>M</u>ean <u>S</u>quare) value of the signal.

A brief definition of RMS for a sine wave is - "the peak voltage of the sine wave multiplied by 0.707", this gives the equivalent DC voltage value that would be required to produce the same power through a fixed resistor.

Scan tools rely on what the vehicle computer sees - it too samples very slow (*much slower than a voltmeter*).

The vehicle computer uses a slow communication bus to talk to the scan tool, this further reduces it's ability to see glitches or transient events. Yet, a digital scope can typically sample signals at more than 1,000,000 times per second, or 1,000 times faster than a fast voltmeter. A scope can display the actual waveform being produced by a sensor or sent by a device.

Let's look at a simple example of an electrical signal the power company sends to your home and the difference between what you would see on a voltmeter and a scope.

117 Volts

Figure 2-C: House Current Displayed on a Voltmeter

In the previous example, the voltmeter has taken the peak value of 165 volts and multiplied it by 0.707 to display 117 volts.

RMS = 117 VOLTS

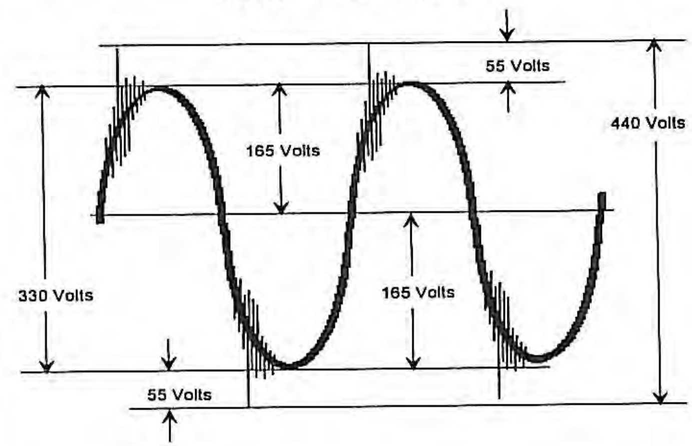


Figure 2-D: House Current Displayed on a Scope

As you can clearly see, the scope shows you a great deal more information than the voltmeter (*notice the spikes*).

The scope you buy today will work with past, present and future vehicle electronics. A typical signal from a fuel injector on a 1970 Volkswagen looks very similar to a 1990 Oldsmobile or 1993 Cummings diesel.

There are typically five types of signals you will find in vehicles. They are:

1. "**Fast repetitive signals**" - such as the signal output by a digital mass air flow sensor.
2. "**Slow repetitive signals**" - such as the control signal for a fuel injector.
3. "**AC signals riding on top of a DC voltage**" - such as the output of a vehicle speed sensor.
4. "**Slow changing voltage**" - such as the output voltage from an analog throttle position sensor.
5. "**Single shot or transient signal**" - such as those found on a park/neutral switch.

Once you become familiar with basic vehicle waveforms it will not matter how new or old the vehicle is, or even who manufactured the vehicle. You will be able to recognize signals that do not look right.

Waveforms are graphical representations of a voltage or current level moving up and down on a vertical or Y axis and displayed over time, from left to right, on a horizontal or X axis. Waveforms allow us to see exactly what is happening to a voltage or current level at a particular moment in time.

A straight diagonal line pointing up from left to right would indicate an increasing voltage or current, where as a straight diagonal line pointing down from left to right would indicate a decreasing voltage or current. This is the type of signal you would expect to see if you placed your scope leads across the terminals of an analog throttle position sensor. As you opened the throttle you would see the voltage increase, and as you closed the throttle you would see the voltage decrease. If you see a sharp angle up or down this would indicate a sudden change in current or voltage.

This is the type of signal you would expect to see if you placed your scope leads across the primary ignition terminals going into a coil. As the coil voltage is cycled on and off you would see sharp edges that would indicate sudden changes in current and voltage.

Waveforms represent a voltage or current level, which is referred to as amplitude, moving up and down on a vertical axis and displayed over time, from left to right, on a horizontal axis. If a waveform is repetitive, like a sine wave, we can measure it's frequency and period. The frequency, which is measured in **H**ert**z** (**Hz**) or **C**ycles **P**er **S**econd (**CPS**), refers to the number of times a signal repeats itself in one second. The period is measured in time and refers to the amount of time it takes for a waveform to complete one cycle. As an example, in the United States, the power company supplies power to your home that has a frequency of 60 Hz. This means that the waveform repeats itself sixty times per second. The period of this waveform would be 1/60 of a second or 16.7 milliseconds or 0.0167 seconds, this is the amount of time it takes to complete one cycle.

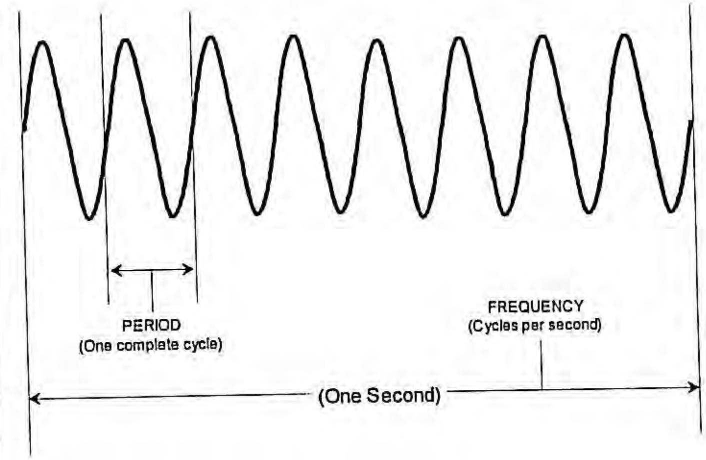


Figure 2-E: Waveform Frequency and Period

*(**Note:** The lab scope will automatically display the frequency of any signal on channel one that is properly triggered and has at least one complete cycle being displayed on the scope. To calculate the period of the signal displayed you can take the reciprocal of the frequency or use the time cursors provided on the lab scope and measure one complete cycle.)*

In the next few pages, we will review several of the most common types of waveforms you are likely to encounter in today's vehicles. Such as constant voltage waveforms, slow changing waveforms, square waves, pulse width modulated waveforms, step waveforms and sine waves.

Waveforms that are produced by the various sensors and monitored by the vehicle's on-board computer must stay within certain boundaries or have certain characteristics that it will recognize to allow the automobile to function as designed. Waveforms that go outside these boundaries can confuse the vehicle's computer and cause driveability problems or basic malfunction of certain systems.

On a Digital Storage Oscilloscope (**DSO**) a constant DC voltage will appear as a flat horizontal line displayed across the screen. The amplitude of the DC voltage can be measured with a DSO by selecting GND (*ground*) coupling, setting the displayed trace to one of the lower horizontal graticule lines and then selecting DC coupling. At a vertical volts/division setting of 5 volts per division, a 12 volt DC signal will move approximately 2 1/2 divisions up above the selected GND (*ground*) reference line on screen.

*(**Note:** On the ADL 7100 you can use the voltage cursors to easily measure the voltage level of a constant DC voltage.)*

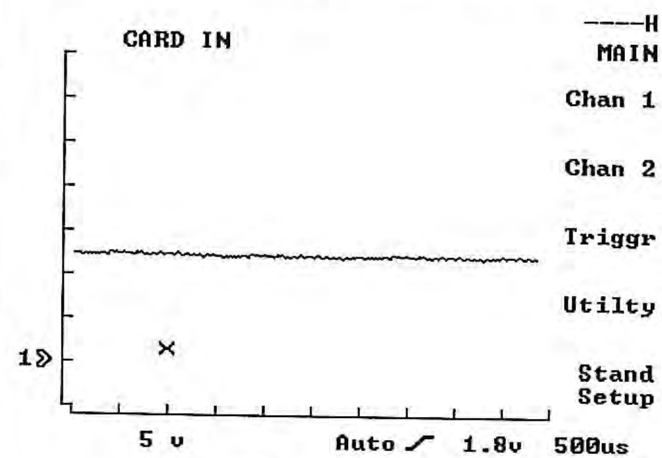


Figure 2-F: Battery Voltage

Most constant DC voltage waveforms found in automobile systems are used as the main power supply to electronic control modules and sensors. In order for these components to perform correctly they must have a supply voltage (*typically 12-15 volts*) and a good return path (*ground*).

A DSO can be used to monitor the DC supply voltage or ground connections while looking for any intermittent shorts or open circuits.

Slowly changing DC voltage waveforms are found in analog (*continuous*) output sensors and components. These sensors and components produce a slowly changing voltage in response to some stimulus (*heat, air flow, throttle movement, exhaust oxygen content, engine vacuum etc.*). Manifold Absolute Pressure (**MAP**) sensors, Throttle Position Sensors (**TPS**), Oxygen (O_2) sensors, analog Mass Air Flow (**MAF**) sensors (*vane type and some hot wire*), Coolant Temperature Sensors (**CTS**) are all examples of sensors that output a slowly changing DC voltage.

The DSO can be used at slower horizontal time base settings (*0.1 seconds or slower*) to view these slowly changing DC waveforms. When viewing slowly changing waveforms the most important characteristic is it's vertical amplitude or voltage and whether the voltage changes within certain boundaries.

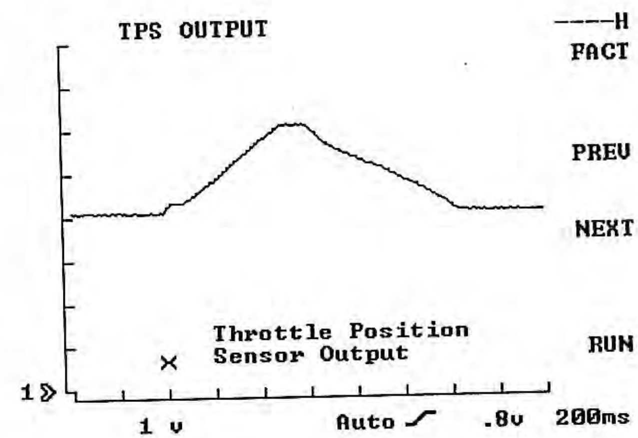


Figure 2-G: Analog Throttle Position Sensor

Square waveforms are produced by an electronic circuit that repeatedly turns a DC voltage on and off. The percentage of "On-time" and the "Off-time" remains the same even as the frequency changes.

Digital MAF sensors, Hall effect and optical crankshaft and camshaft position sensors, ignition reference waveforms, are all examples of square waveforms. These sensors output square waveforms that typically increase in frequency as the engine RPM or load increases.

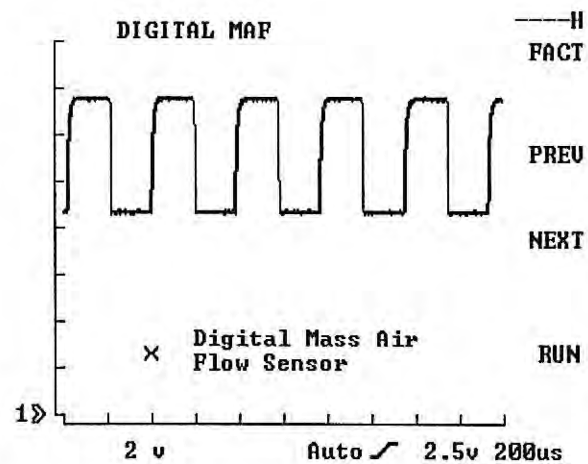


Figure 2-H: Digital Mass Air Flow Sensor Output

Some important characteristics of square waveforms are their on and off vertical voltage amplitude, how many on and off cycles occur per second (*frequency in Hertz*), and their shape (*clean and symmetrical*).

Some square waves modulated pulse widths and are called Pulse Width Modulated or (**PWM**) waveforms. These waveforms have changing or modulated pulse widths.

Examples of PWM square waveforms can be found in mixture control solenoids, canister purge solenoids, idle air control solenoids, fuel injector waveforms, Electronic Spark Timing (**EST**) waveforms, blower motor speed control waveforms, transmission shift control solenoids, ignition coil primary waveforms, and even some electric fuel pump control waveforms.

Some important characteristics of a PWM waveform are it's vertical voltage amplitude, on-time and off-time (*duty cycle*), shape and whether the duty cycle changes as required by changing engine loads or speed.

PWM waveforms have on and off times that change frequently to regulate the average amount of voltage to a device.

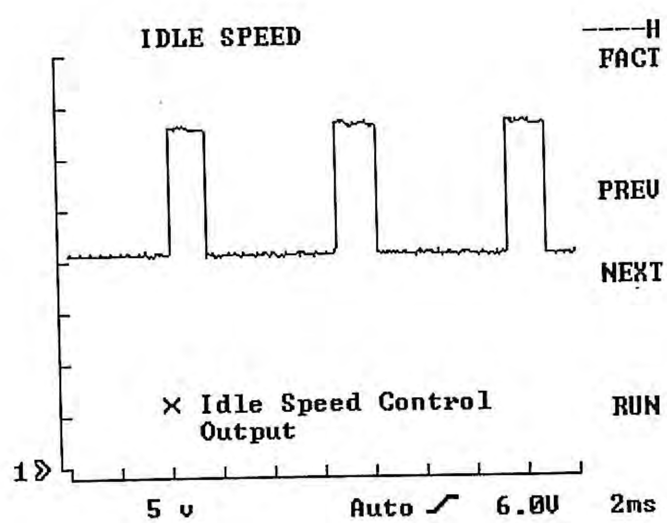


Figure 2-I: Idle Speed Control Signal

Step voltage waveforms can be found at the park/neutral switch as the selector is changed from park to drive or reverse.

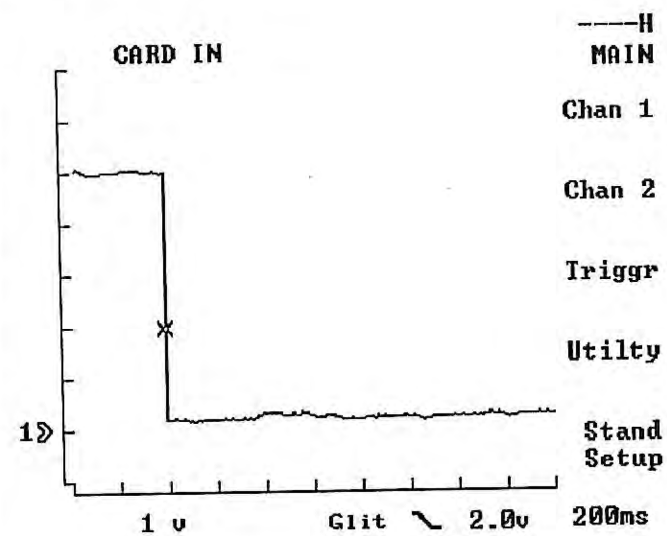


Figure 2-J: Park/Neutral Switch

Sine waves are AC voltage waveforms that have voltage levels above and below a DC voltage reference level. When displaying sine waves, set the DC GND (*ground*) reference line to the center horizontal graticule line. Then set the AC input coupling to block out the DC voltage and view the signal above and below the reference line.

Some important characteristics of the sine waves are their peak-to-peak voltage amplitude, the time duration of the signal (*period or frequency*) and the appearance or shape of the waveform.

*(**Note:** The lab scope voltage cursors are especially useful when measuring a peak-to-peak voltage amplitude. Place one voltage cursor on the top of the waveform and the other at the bottom of the waveform, the readout in the upper right corner of the display will show the peak-to-peak voltage.)*

Sine waves are produced by <u>A</u>nti-Lock <u>B</u>rake <u>S</u>ystem (**ABS**) magnetic wheel speed sensors, magnetic vehicle speed sensors, and by the charging system alternator.

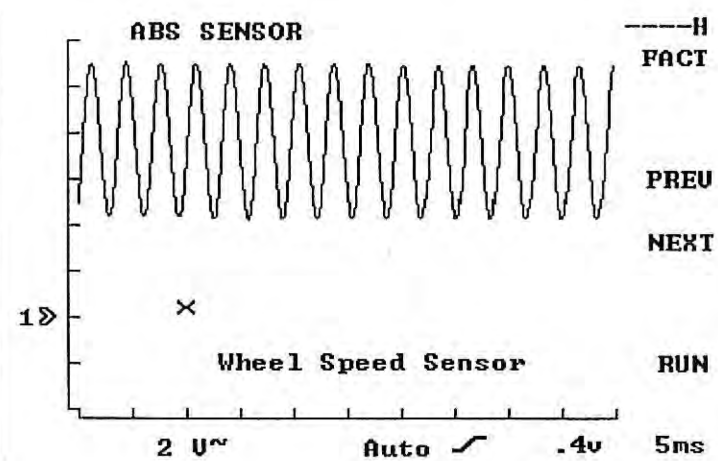


Figure 2-K: ABS Sensor Output

Chapter 3 - Oscilloscope Basics

The oscilloscope is basically a graph-displaying device, that draws a graph of an electrical signal. In most applications the graph shows how signals change over time: the vertical axis represents voltage and the horizontal axis represents time. This simple graph can tell you many things about a signal. Here are just a few:

- ❑ *You can determine the time and voltage values of a signal.*
- ❑ *You can calculate the frequency of an oscillating signal.*
- ❑ *You can see the "moving parts" of a circuit represented by the signal.*
- ❑ *You can tell if a malfunctioning component is distorting the signal.*
- ❑ *You can find out how much of a signal is direct current (DC) or alternating current (AC).*
- ❑ *You can tell how much of the signal is noise and whether the noise is changing with time.*
- ❑ *You can compare known "Good" waveforms with "Live" waveforms.*

Analog and Digital Oscilloscopes

Oscilloscopes can be divided into two types: analog and digital. Analog oscilloscopes directly display continuously variable signals, while digital oscilloscopes convert these signals to discrete binary data that digitally represent the signal being acquired. An example of this is, a conventional phonograph turntable is an analog device, directly converting the record grooves into sound, on the other hand a compact disc player is a digital device, that takes discrete binary data and converts it to sound.

An analog oscilloscope works by directly applying a voltage being measured to an electron beam moving across the oscilloscope screen. The voltage deflects the beam up and down proportionally, tracing the waveform on the screen. In contrast, a digital oscilloscope samples the waveform and uses an Analog-to-Digital Converter (**ADC**) to convert the voltage being measured into digital information. It then uses this digital information to reconstruct the waveform on the screen.

Each type of oscilloscope does possess some unique characteristics making it more or less suitable for specific tasks. For instance, analog oscilloscopes can display rapidly varying signals in "real time" (*or as they occur*). However, they can not capture and store signals for analysis and comparison, like digital oscilloscopes.

Digital oscilloscopes even allow you to capture and view events that may happen only once. Also, they can process the digital waveform data and display it or send the data to a computer for processing.

Since they can store the digital waveform data in memory or on a computer this allows viewing and printing at a later time, next week or even next year.

To better understand the oscilloscope controls, you need to know a little more about how oscilloscopes display a signal. Analog oscilloscopes work somewhat differently than digital oscilloscopes. However, several of the internal systems are similar. Analog oscilloscopes are somewhat simpler in concept.

When you connect an oscilloscope probe to a circuit, the voltage signal travels through the probe to the vertical system of the oscilloscope. Depending on how you set the vertical scale (*volts/div control*), an attenuator reduces the signal voltage or an amplifier increases the signal voltage.

Next, the signal travels directly to the vertical deflection plates of the Cathode Ray Tube (**CRT**). Voltage applied to these deflection plates causes a glowing dot to move. (*An electron beam hitting phosphor inside the CRT creates the glowing dot.*)

A positive voltage causes the dot to move up while a negative voltage causes the dot to move down.

The signal also travels to the trigger system to start or trigger a "horizontal sweep." Horizontal sweep is a term referring to the action of the horizontal system causing the glowing dot to move across the screen. Triggering the horizontal system causes the horizontal time base to move the glowing dot across the screen from left to right within a specific time interval. Many sweeps in rapid sequence cause the movement of the glowing dot to blend into a solid line. At higher speeds, the dot may sweep across the screen up to 500,000 times each second.

Together, the horizontal sweeping action and the vertical deflection action traces a graph of the signal on the screen. The trigger is necessary to stabilize a repeating signal. It ensures that the sweep begins at the same point of a repeating signal, resulting in a clear picture.

In order to use an analog or digital oscilloscope, you need to adjust three basic settings to accommodate an incoming signal:

1) <u>The attenuation or amplification of the signal</u>. *Use the volts/div control to adjust the amplitude of the signal before it is displayed on the screen.*

2) <u>The time base</u>. *Use the sec/div control to set the amount of time per division represented horizontally across the screen.*

3) <u>The triggering of the oscilloscope</u>. *Use the trigger level to stabilize a repeating signal, as well as triggering on a single event.*

Also, adjusting the focus and intensity controls will help you to create a sharp, visible display on analog scopes

Digital oscilloscopes contain additional data processing and acquisition systems, not available on analog scopes. The digital oscilloscope first collects data for the entire waveform and then displays it.

When you connect a probe to a circuit, the vertical system adjusts the amplitude of the signal, just as in the analog oscilloscope.

Next, the ADC in the acquisition system samples the signal at discrete points in time and converts the signal's voltage at these points to digital values called "sample points". The horizontal system's sample clock determines how often the ADC takes a sample. The rate at which the clock "ticks" is called the "sample rate" and is measured in "samples per second". Then the sample points from the ADC are stored in memory as waveform points.

Together, the sampled points make up one waveform record. The number of waveform points used to make a waveform record is called the "record length".

*(**Note:** The ADL 7100 runs at a sample rate of up to 5 million samples per second. In most cases, more than one sample point will make up one waveform point. The ADL 7100 stores the highest and lowest sampled point. This prevents signal aliasing.)*

The trigger system determines the starting point of the record. The display receives these record points after being stored in memory.

As a reminder, on both digital and analog oscilloscopes, you need to adjust the vertical, horizontal and trigger settings to properly display a waveform.

Signal Probing with an Oscilloscope

The engine compartment of a running vehicle is a very unfriendly environment for automotive signals to live. Temperature extremes, dirt and corrosion, and electrical leaks, or "noise" from the high voltage pulses from a typical ignition system can produce interference that can contribute significantly to the cause of many driveability complaints.

Have you ever found that a car phone was the cause of a driveability complaint?

When you are probing components, sensors and circuits, be aware that the electrical "noise" from today's high output ignition systems can produce an **RF** (Radio Frequency) energy that is similar to a radio station. Since oscilloscopes are so sensitive, this interference can actually override the signals you are trying to capture and give you a false reading on the display.

To minimize this possible interference with the oscilloscope, try to remember these tips and suggestions:

- Most interference will be picked up by the oscilloscope test leads.

  A. Route the test leads away from all ignition wires and components whenever possible.

  B. With the potential for RF interference in the engine compartment, if possible, use the vehicle chassis as ground when connecting the oscilloscope test leads. In some cases the engine block can actually act as an antenna for the RF signals.

  C. Use the shortest test leads possible, since other test leads may act as an antenna and increase the potential for interference, especially at higher frequency levels that are found when probing near the vehicle's on-board computer.

  D. The test leads are a very important part of any lab scope. The test leads supplied with your ADL 7100 are designed to operate with signals up to 500 kHz, which is the rated bandwidth of the oscilloscope. Substituting other leads in both length and capability may alter the signals on your display.

- Like the test leads, the lab scope can also pick up interference.

  A. Because the circuits of a lab scope are so sensitive, and therefore powerful, do not place the lab scope directly on ignition wires or near high energy ignition components, like coil packs.

  B. If you are using the AC or DC charger/adapter to power the ADL 7100, keep the external power leads away from the engine and ignition if possible.

Learning a new skill often involves learning a new vocabulary. This idea holds true for learning how to use an oscilloscope. There are many terms to describe the types of measurements you can make with your oscilloscope. The following describes some of the most common measurement terms.

Frequency and Period
If a signal repeats, it has a frequency. The frequency is measured in Hertz (**Hz**) and equals the number of times the signal repeats itself in one second (*the cycles per second*).

A repeating signal also has a period - this is the amount of time it takes the signal to complete one cycle. Frequency and period are reciprocals of each other, so that 1/period equals the frequency and 1/frequency equals the period. So, for example, if a certain sine wave has a frequency of 3 Hz, it will have a period of 1/3 second.

Voltage
Voltage is the amount of electric potential (*a kind of signal strength*) between two points in a circuit. Usually one of these points is ground (*zero volts*) but not always. You may want to measure the voltage from the maximum peak to the minimum peak of a waveform, referred to as the peak-to-peak voltage. The word amplitude commonly refers to the maximum voltage of a signal measured from ground or zero volts.

Phase
Phase is best explained by looking at a sine wave. Sine waves are based on circular motion and a circle has 360°. One cycle of a sine wave has 360°.

Using degrees, you can refer to the phase angle of a sine wave when you want to describe how much of the period has elapsed.

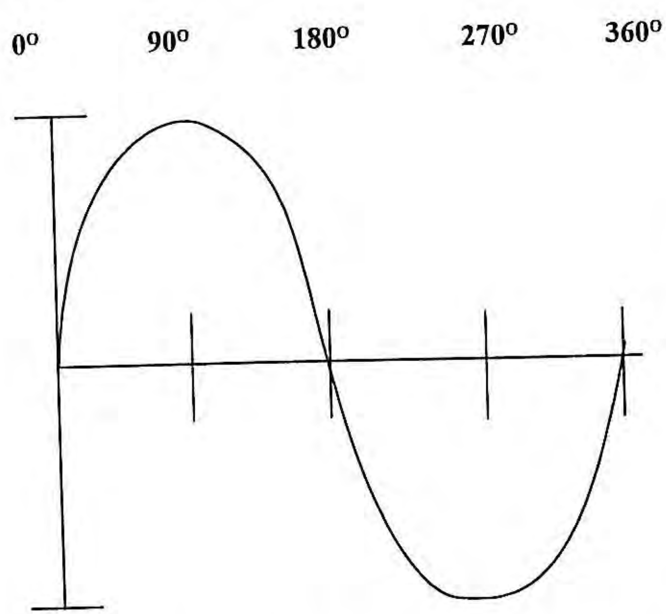


Figure 3-A: Phase of a Sine Wave in Degrees

Phase Shift

Phase shift describes the difference in timing between two otherwise similar signals, as shown below.

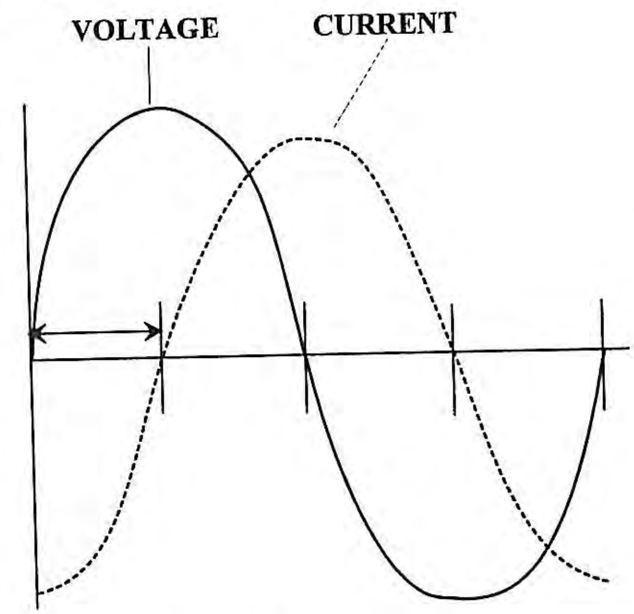


Figure 3-B: Phase Shift

For example, using a sine wave from a standard AC outlet, the "current" waveform is said to be 90° out of phase with the "voltage" waveform, since the sine waves reach similar points in their cycles exactly 1/4 of a cycle apart (*360°/4 = 90°*). The voltage and current waveforms are said to have a 90° phase shift. Phase shifts are very common in electronics.

Aliasing

Aliasing occurs when a digital oscilloscope does not take enough samples on a particular signal. After the oscilloscope reconstructs and displays the waveform you can be "fooled" into seeing a false waveform. The ADL 7100 uses Min/Max acquisition at all sweep speeds, this prevents the scope from aliasing a waveform. Aliasing can be a problem when viewing signals on oscilloscopes, since you never know when it is occurring, you can be "fooled" into seeing a false waveform.

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Chapter 4 - Lab Scope Features and Functions

Product Description
The ADL 7100 is a portable two channel digital oscilloscope designed expressly for use in the automotive service market. The main purpose of the ADL 7100 is to provide advanced troubleshooting capabilities for automotive service technicians in an easy to operate format. The lab scope is capable of providing both amplitude and timing information on signals up to 500 kHz at a sampling rate of up to 5 megasamples per second.

An interchangeable memory card is provided for comparison to stored known good waveforms. Individual settings are also stored in the plug-in card along with waveform information. This way a technician can look up a known pattern in the card memory and have the scope set itself up for the measurement and at the same time display the good signal to compare. Easy to use cursors are available for making more precise voltage and timing measurements.

Power is supplied via an internal lead acid battery as well as an external adapter/charger.

An optional RS-232 adapter is also available for interfacing to a computer for mass waveform storage and to print the ADL 7100 display to a printer.

All automotive features are accessed by soft push buttons. In most cases, changes are indicated on the LCD screen in a position adjacent to the control.

To assist the operator there is a factory standard setup that always defaults to channel 1 only positioned to the center of the screen with DC coupling, auto-trigger with a trigger level of 2.5 volts, vertical set to 5 volts/division, horizontal set to 5 milliseconds/division and cursors turned off. All menus are only one level deep to avoid confusion during operation.

Theory of Operation
Two separate channels with a common ground are used for signal input. Signal conditioning consists of two attenuators with a bandwidth exceeding 500 kHz. The attenuators use an exclusive design that limits the number of mechanical relays to one per channel.

The oscilloscope is controlled by a single M68HC11 microprocessor. The processor handles all of the internal housekeeping and display functions. The analog inputs are digitized at a rate of up to 5 megasamples per second and directed to a DSP-2105 digital signal processor which handles all signal processing and math manipulation. The Min/Max acquisition is used at all sweep speeds, this prevents the scope from aliasing a waveform.

Aliasing can be a problem when viewing signals on other digital oscilloscopes, since you never know when it is occurring, you can be "fooled" into seeing a false waveform, as mentioned earlier.

*(**Note:** Since the ADL 7100 was designed to be used by a wide variety of users, it was important to incorporate a design that would prevent aliasing. The ADL 7100 uses a digital sampling method call "Min/Max", this prevents aliasing from ever occurring.)*

The LCD display unit incorporates it's own internal display drivers and an electroluminescent backlight.

The operating system resides on an **OTP** (One Time Programmable) 128K memory plug-in card. On power-up, the processor checks the version of software that is resident on the card, if a later version is present, the oscilloscope will automatically be up-dated.

*(**Note:** Once the operating system is loaded from the card to internal memory the ADL 7100 will operate without the card as long as the internal battery is charged or connected to the external adapter. Attempting to recall a waveform from the card when it is not installed may also affect the operating system in memory.)*

CAUTION - To be safe, you should always operate the scope with the card installed.

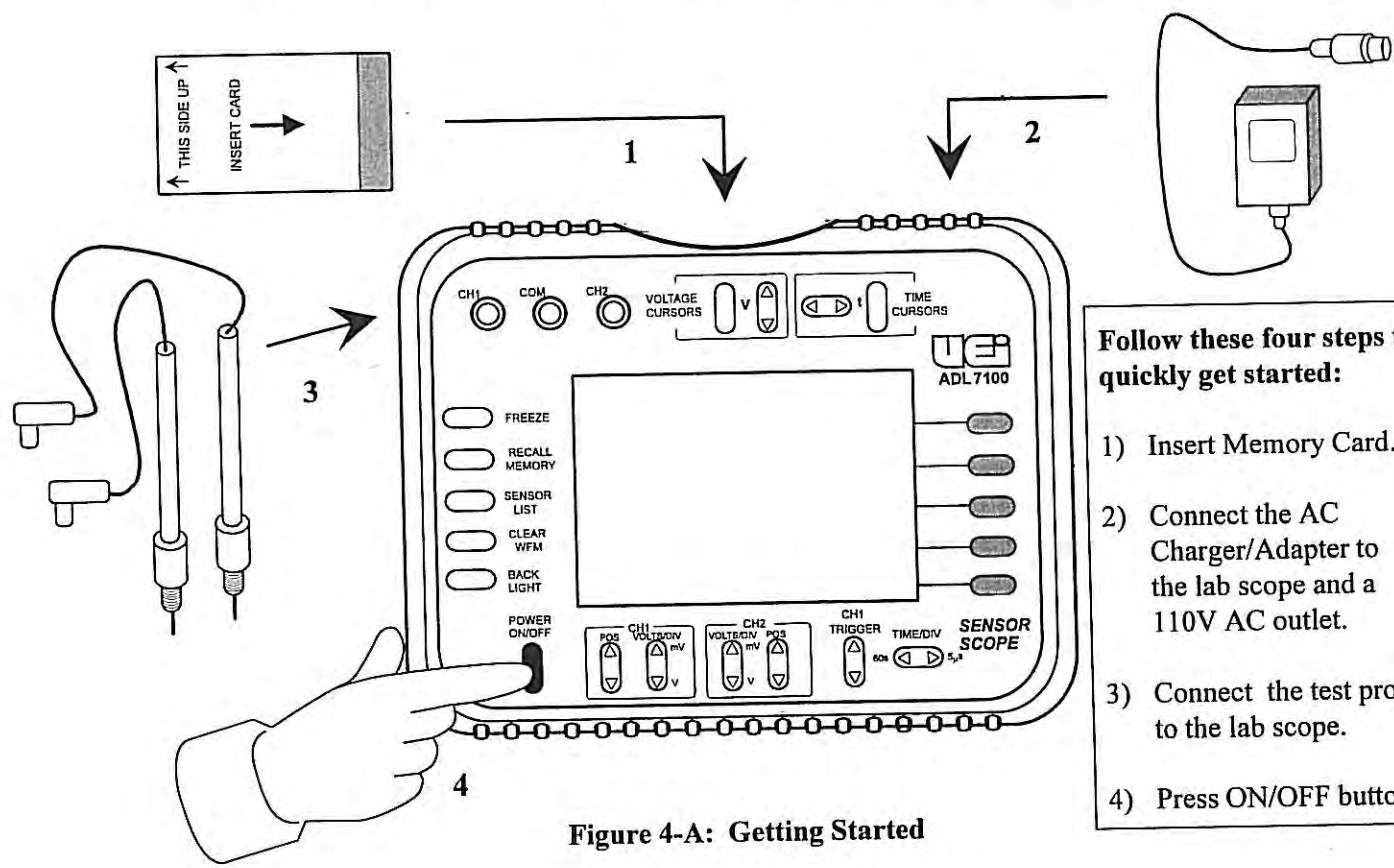


Figure 4-A: Getting Started

Follow these four steps to quickly get started:

1) Insert Memory Card.

2) Connect the AC Charger/Adapter to the lab scope and a 110V AC outlet.

3) Connect the test probes to the lab scope.

4) Press ON/OFF button

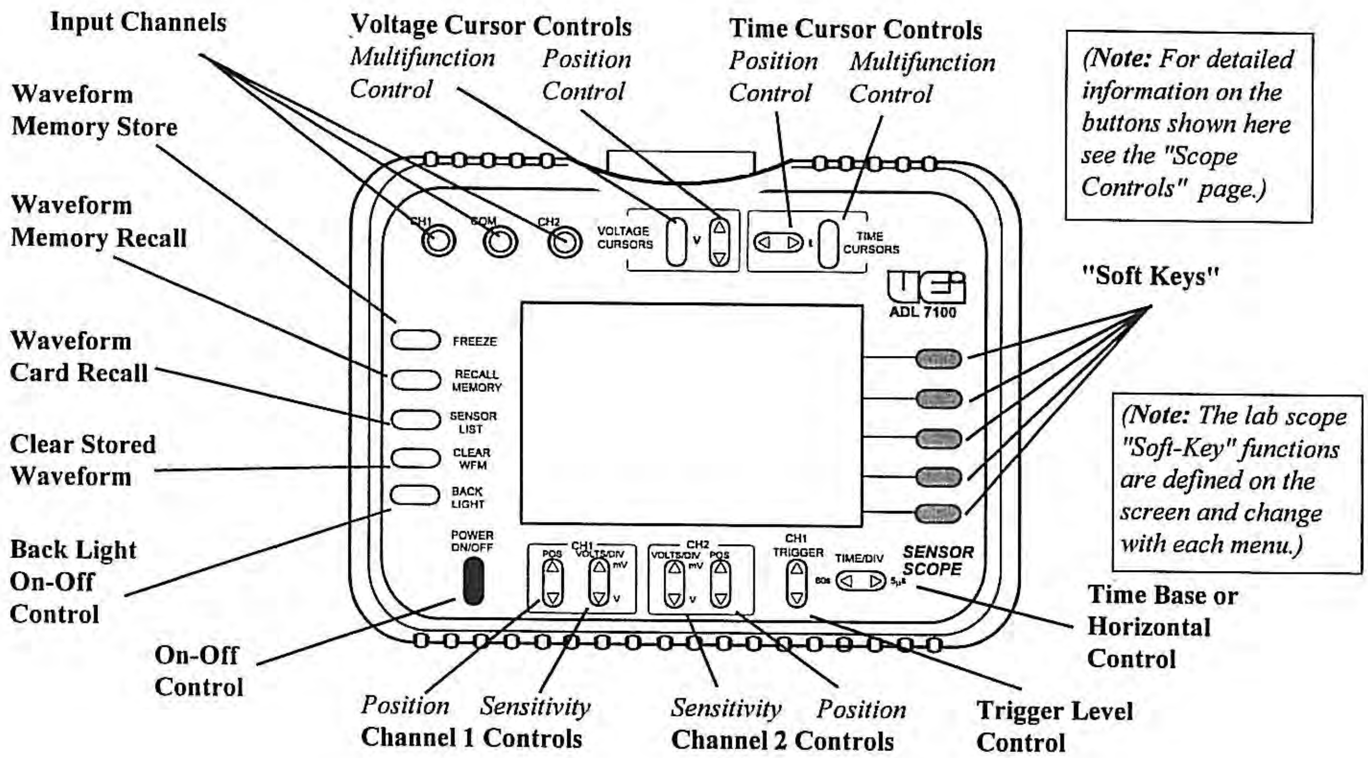


Figure 4-B: Front Panel Controls and Soft Keys

SCOPE CONTROLS :

On-Off Control - *Green instrument power on-off button. Instrument goes through a self-test when first powered on, if no problems are found, the oscilloscope will power up in the last setup used.*

Channel 1 Controls
Sensitivity - *Controls the volts per division setting on channel one. Up increases sensitivity and down decreases.*

Position - *Controls the vertical position of the channel one trace on the display.*

Channel 2 Controls
Sensitivity - *Controls the volts per division setting on channel two. Up increases sensitivity and down decreases.*

Position - *Controls the vertical position of the channel two trace on the display.*

Trigger Level Control - *Sets the trigger level on channel one only.*

Time Base or Horizontal Control - *Sets the horizontal sweep speed from 60 seconds per division to 5 microseconds per division.*

Voltage Cursor Controls
Multifunction Control - *Turns the voltage cursors on and off and toggles to each cursor.*

Position Control - *Controls the vertical position of the voltage cursors on the display.*

Time Cursor Controls
Multifunction Control - *Turns the time cursors on and off and toggles to each cursor.*

Position Control - *Controls the horizontal position of the time cursors on the display.*

Input Channels - *The red inputs for channel one and two are the high inputs and the black input is the common or low input for both channels.*

SCOPE CONTROLS (continued):

*(**Note:** Since this scope is considered to be "floating" - that is, it is not connected to a ground - in order to properly make measurements that are referenced to ground, you must physically connect the common input to ground.)*

Waveform Memory Store - *Captures live waveforms on the screen for storage in one of four locations.*

Waveform Memory Recall - *Recalls stored waveforms and front panel setups from one of four locations.*

Waveform Card Recall - *Recalls waveforms and front panel setups stored on the memory card.*

Clear Stored Waveform - *Removes the stored waveform from the display and returns the scope to normal operation.*

Back Light On-Off Control - *Toggles the backlight on and off for use in low level or difficult lighting conditions.*

*(**Note:** Turning on the backlight increases battery power consumption to a very high level. If the ADL 7100 is going to be used for more than 30 minutes at a time, external power is recommended.)*

Frequency Readout - *The frequency of channel one is always displayed in the upper right corner of the display.*

*(**Note:** The frequency will only be displayed if at least one complete cycle is displayed on the screen and the scope is properly triggered. The signal must be less than 500 kHz. If the frequency is not available, ----H will appear on the display.)*

"Soft Keys" - *These keys are menu driven. The functions of these keys are determined by the menu selected and are defined on the right side of the screen.*

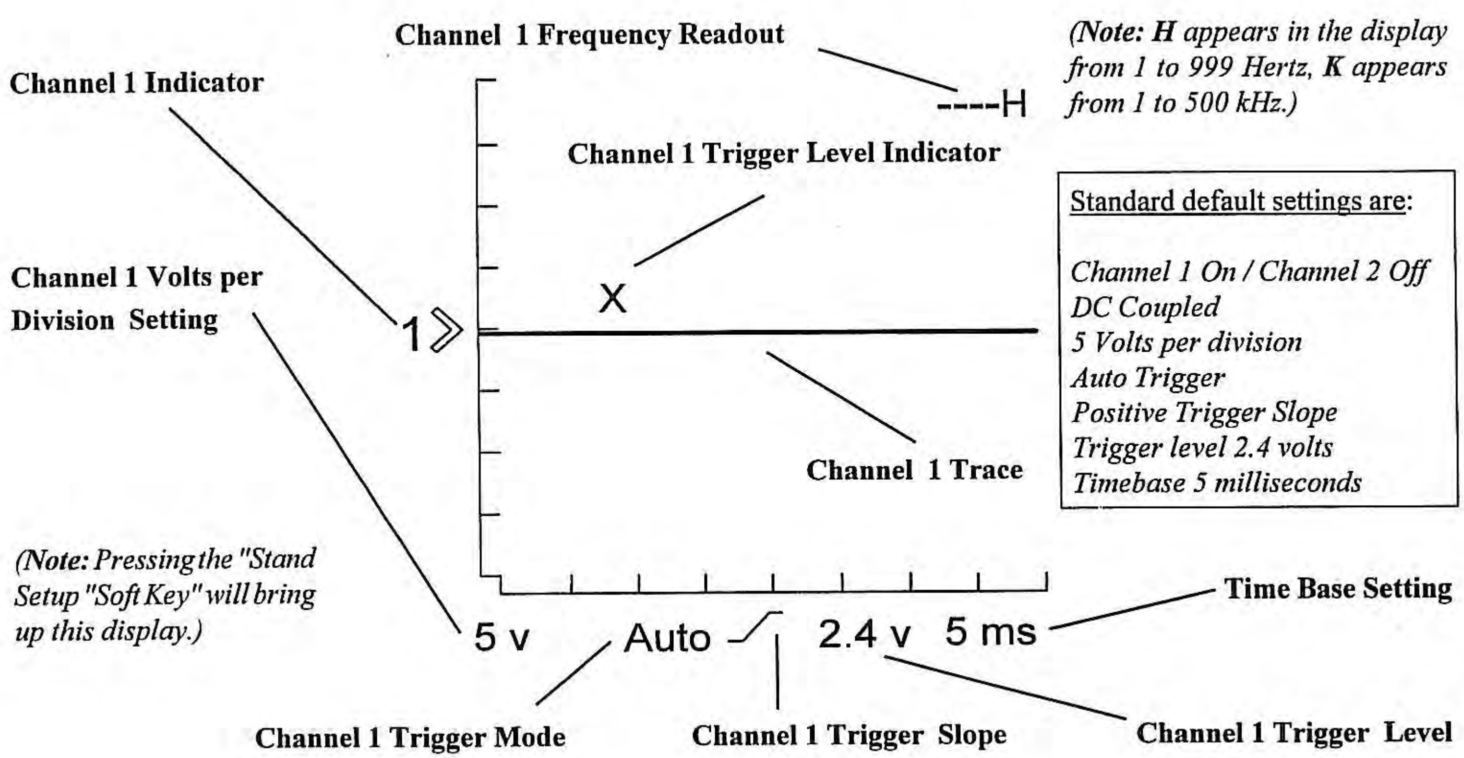
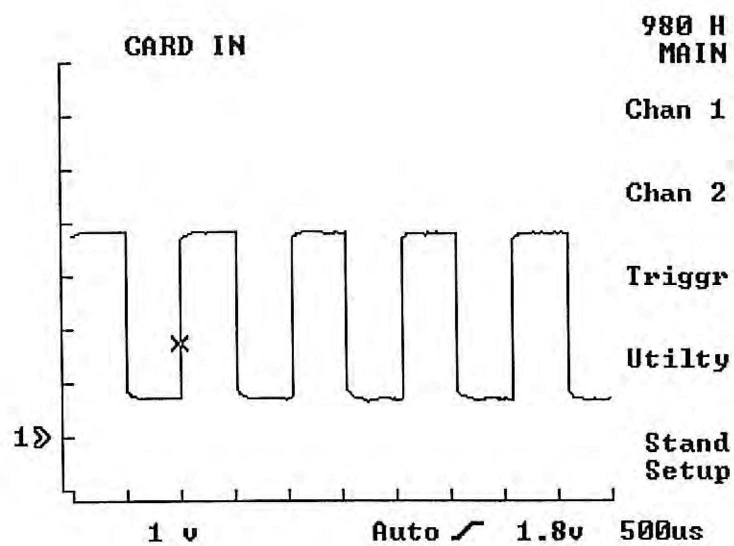


Figure 4-C: Lab Scope Display Layout



MAIN - *Main menu.*

Chan 1 -*Selects input signal coupling for Channel 1.*

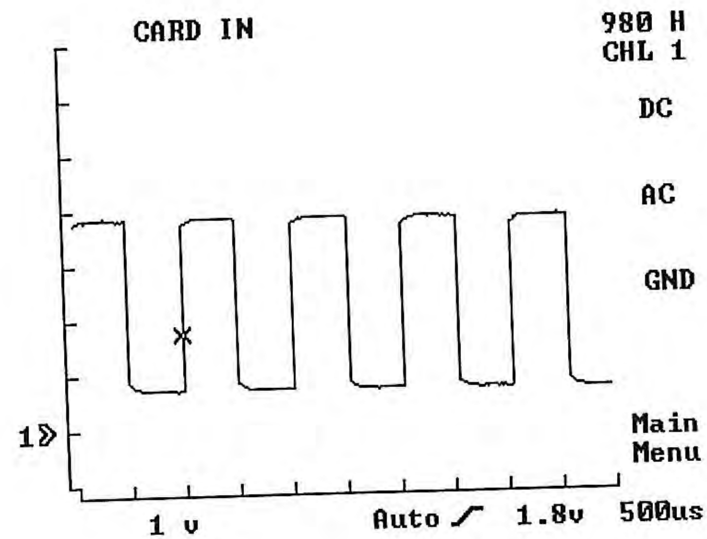
Chan 2 - *Turns ON or OFF Channel 2 and selects input signal coupling.*

Triggr - *Selects trigger mode and slope.*

Utilty - *Allows access to contrast control and interface functions for printer and computer.*

Stand Setup - *Returns the lab scope to a setup that is predetermined.*

Figure 4-D Main Menu



CHL 1 - *Channel 1 menu.*

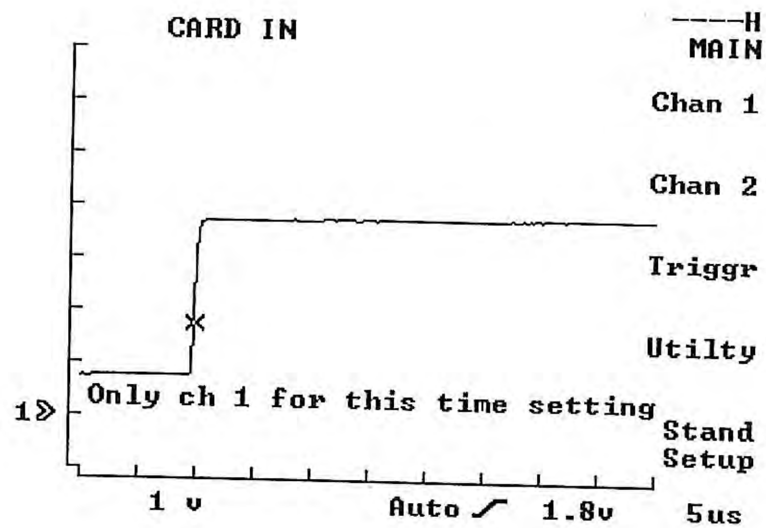
DC - *DC coupling allows the DC component of the signal to be included on the oscilloscope display.*

AC - *AC coupling removes the DC component of the input signal.*

GND - *Grounds the input of the scope internally.*

Main Menu - *Returns lab scope to the Main Menu.*

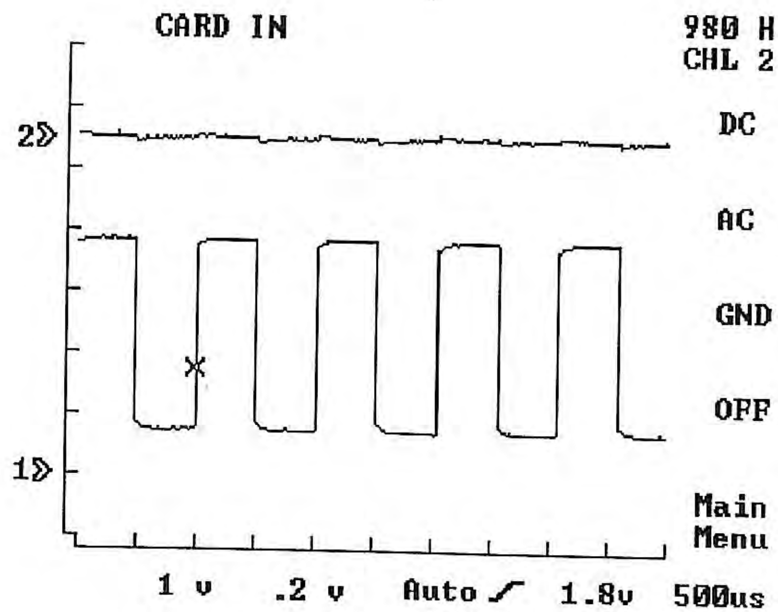
Figure 4-E: Channel 1 Menu



Time Base Warning Message

*(**Note:** This warning message is given when trying to use the 5 μs time base setting with channel 2 on.)*

Figure 4-F: Time Base Warning Message



CHL 2 - *Channel 2 menu.*

DC - *DC coupling allows the DC component of the signal to be included on the lab scope display.*

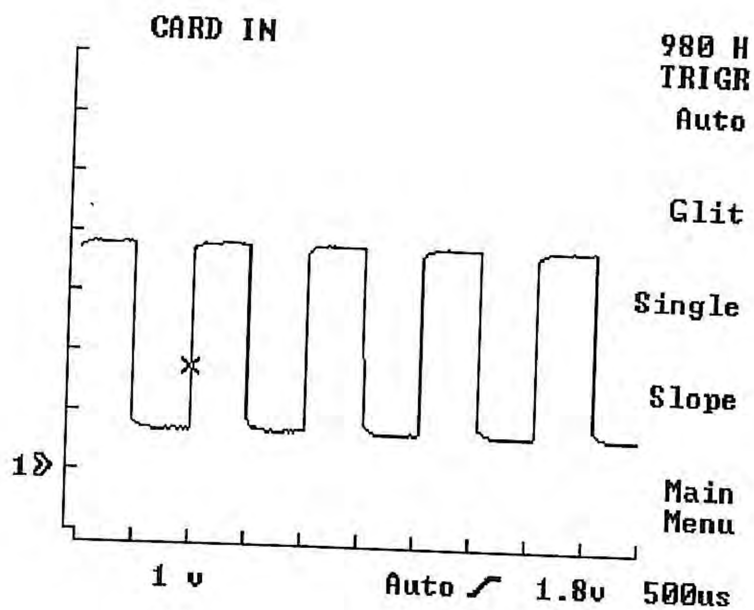
AC - *AC coupling removes the DC component of the input signal.*

GND - *Grounds the input of the scope internally.*

OFF - *Turns off only channel 2.*

Main Menu - *Returns lab scope to the Main Menu.*

Figure 4-G: Channel 2 Menu



TRIGR - *Trigger menu.*

Auto - *Looks for a trigger signal, if one is not present the oscilloscope will free run.*

Glit - *In this trigger mode the lab scope will not display a trace until a trigger occurs.*

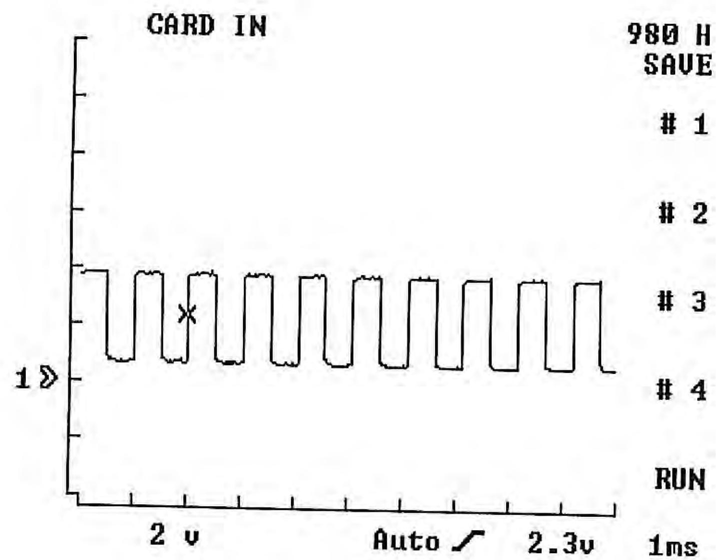
*(**Note:** The horizontal trigger position is fixed at two divisions from the left. The vertical trigger level can be adjusted using the CH1 trigger level button.)*

Single - *Triggers the lab scope once each time it is pressed.*

Slope - *Changes the trigger from the positive ∫ to the negative \ slope of the signal. Pressing it again, toggles it back.*

Main Menu - *Returns lab scope to the Main Menu.*

Figure 4-H: Trigger Menu



SAVE - *Freeze menu.*

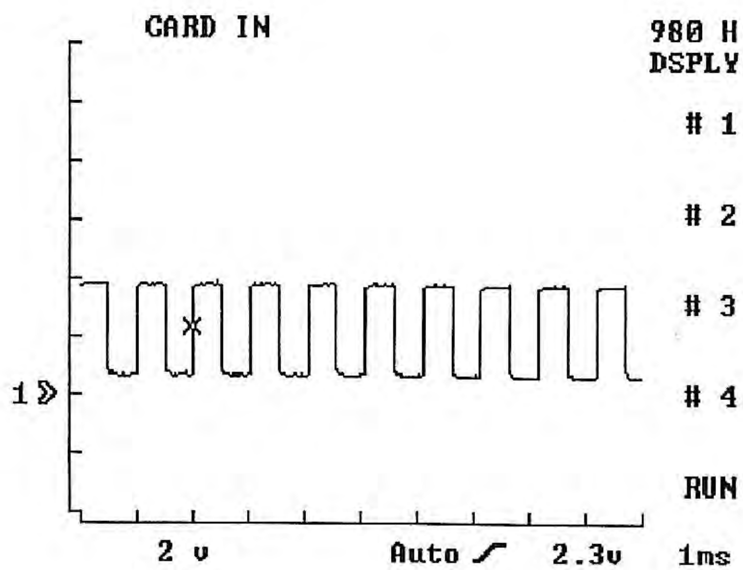
#1 to # 4 - *Allows you to store a waveform in memory locations 1 to 4.*

*(**Note:** The lab scope also stores the front panel setup with the waveform. To clear a stored location, you can write over the location with another waveform and front panel settings.)*

RUN - *Returns the lab scope to the Main Menu.*

*(**Note:** Freezing a waveform will not store the frequency value. However, you can calculate the frequency by using the time cursors and calculating the reciprocal.)*

Figure 4-I: Freeze Menu



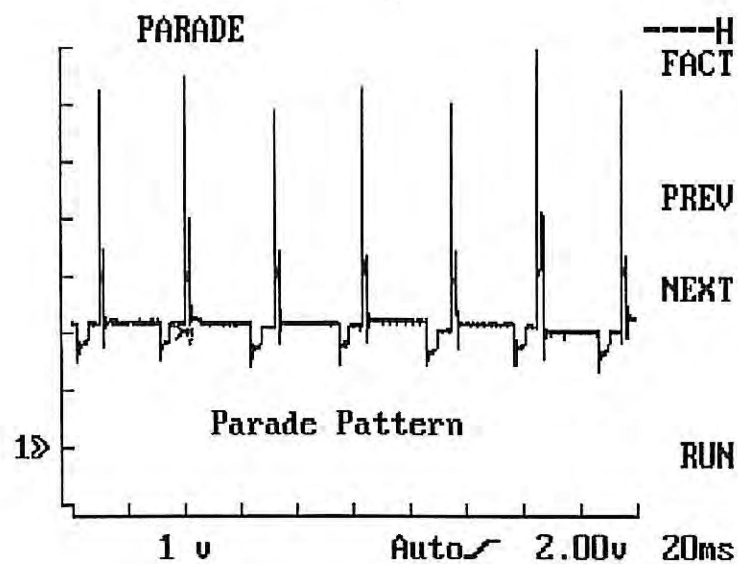
DSPLY - *Recall memory menu.*

#1 to # 4 - *Allows you to recall a stored waveform from memory location 1 to 4.*

*(**Note:** The lab scope also recalls the front panel setup that was stored with the waveform.)*

RUN - *Returns the lab scope to the Main Menu and continues to display the stored waveform for comparison to a live waveform.*

Figure 4-J: Recall Memory Menu



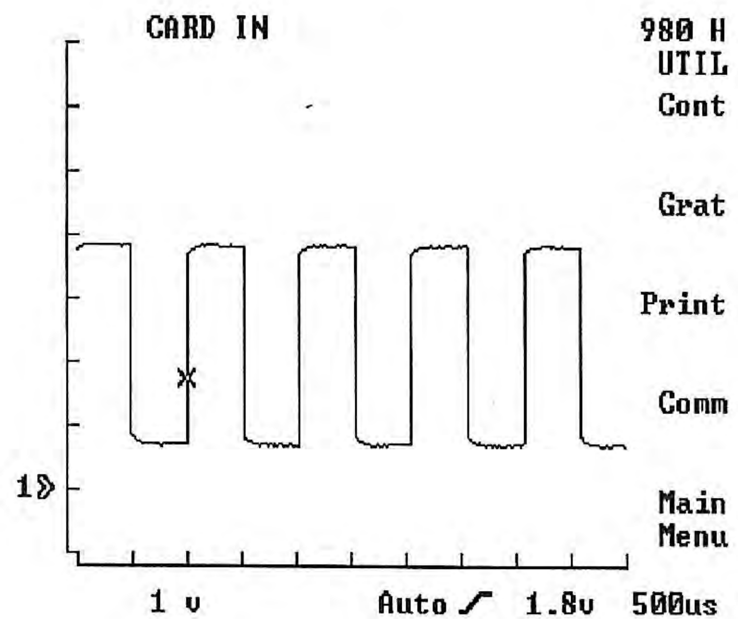
FACT - *Factory stored waveform menu.*

PREV - *Recalls the previous reference waveform stored on the memory card. Repeatedly pressing this button scrolls to each previous consecutive stored waveform.*

NEXT - *Advances to the next reference waveform stored on the memory card. Repeatedly pressing this button scrolls to each next consecutive stored waveform.*

RUN - *Returns the lab scope to the Main Menu and continues to display the stored waveform for comparison to a live waveform.*

Figure 4-K: Recall Card Menu



UTIL - *Utility menu.*

Cont - *The contrast control scrolls through several levels of adjustment to compensate for glare or varying levels of light.*

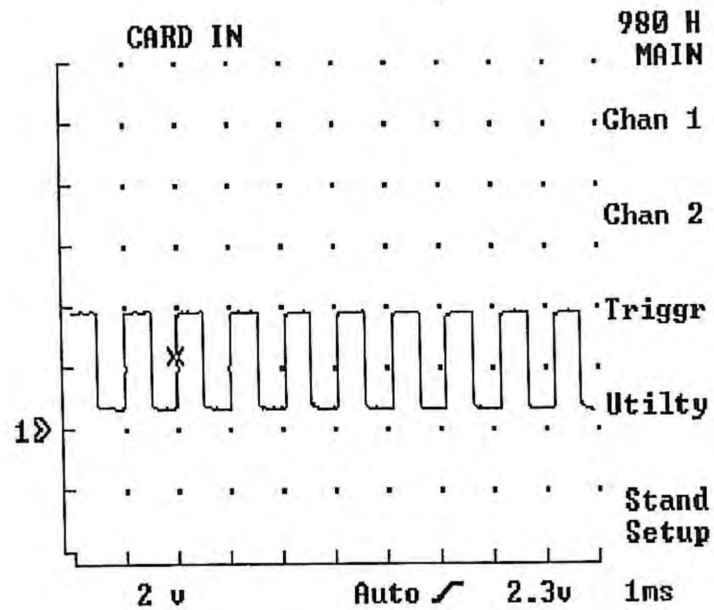
Grat - *Displays a dot type graticule.*

Print - *Allows you to print the display directly to any Epson compatible printer.* ***(Note:*** *This requires an optional RS-232 interconnect cable and software.)*

Comm - *Begins communication with a computer via the RS-232 interface.* ***(Note:*** *This requires an optional RS-232 interconnect cable and software.)*

Main Menu - *Returns lab scope to the Main Menu.*

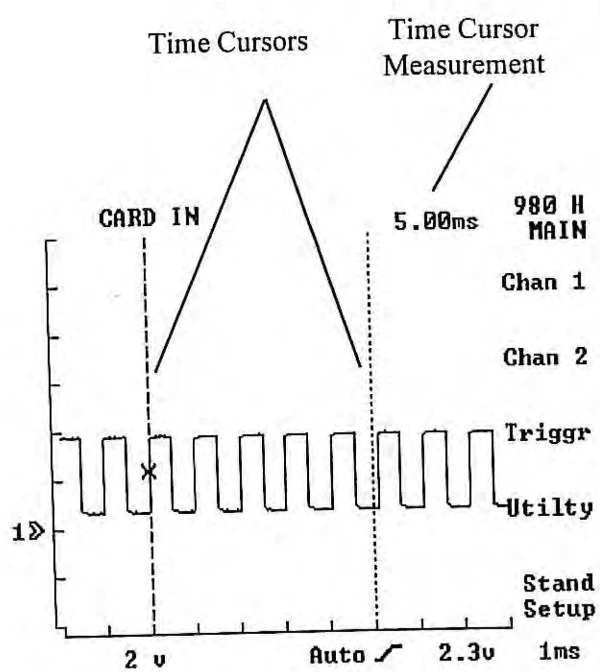
Figure 4-L: Utility Menu



Shown to the left, is the display graticule that is accessed through the Utility menu. The "**Grat**" button displays a dot type graticule to assist in making visual voltage and timing measurements. The distance between adjacent dots is one division.

The graticule also allows you to easily compare waveforms between channel 1 and channel 2 and stored waveforms for timing and voltage differences.

Figure 4-M: Graticule Display



Using the Time Cursors

When a signal is displayed, follow these steps to make a timing measurement:

1. Press the cursor toggle button to turn on the time cursors.
2. Press the cursor movement button to position the first reference line.
3. Press the cursor toggle button to select the other reference line.
4. Press the cursor movement button to position the other reference line.
5. Read the time between the cursors in the upper right corner.
6. Press the cursor toggle button again to turn off the cursors.

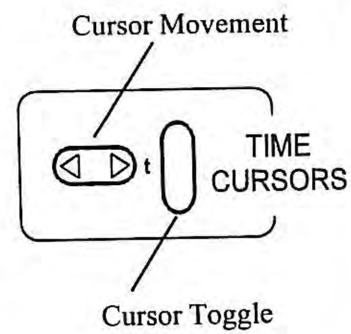
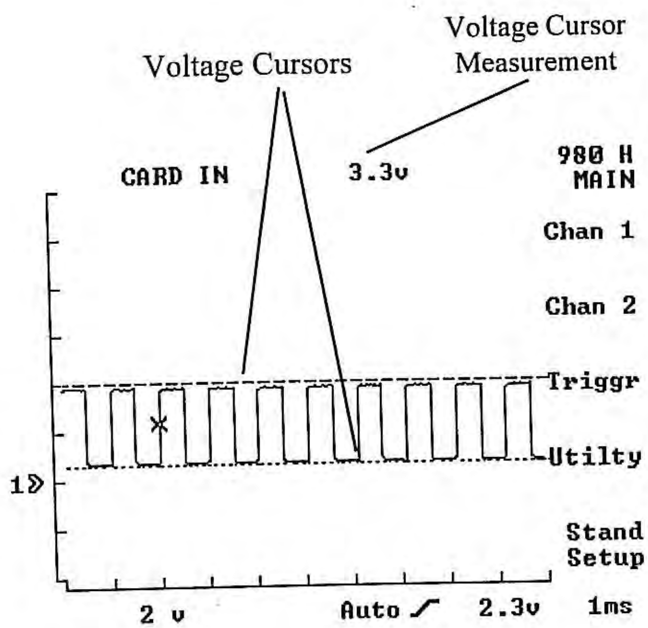


Figure 4-N: Time Cursors



Using the Voltage Cursors

When a signal is displayed, follow these steps to make a voltage measurement:

1. Press the cursor toggle button to turn on the time cursors.
2. Press the cursor movement button to position the first reference line.
3. Press the cursor toggle button to select the other reference line.
4. Press the cursor movement button to position the other reference line.
5. Read the volts between the cursors in the upper right corner.
6. Press the cursor toggle button again to turn off the cursors.

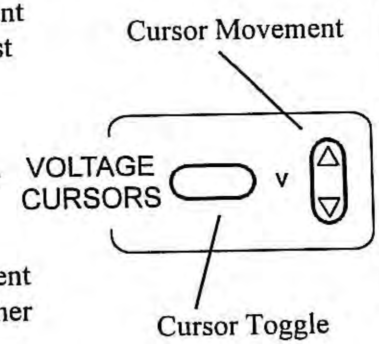
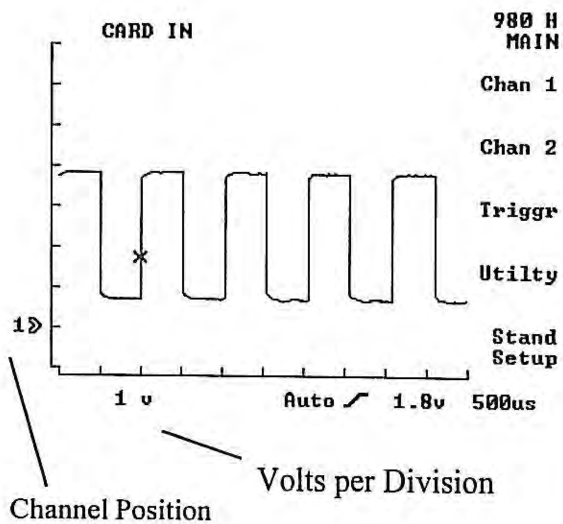


Figure 4-O: Voltage Cursors



*(**Note:** Increasing the volts/div on the display makes the signal appear smaller, decreasing the volts/div on the display makes the signal appear larger.)*

Changing Volts/Div & Position

Follow these steps to change the volts/div and the position, using a live, repetitive waveform:

1. To increase the volts/div on channel 1 press the bottom of the volts/div button.
2. To decrease the volts/div on channel 1 press the top of the volts/div button.
3. To position the channel 1 waveform up on the screen, press the top of the channel 1 position button.
4. To position the channel 1 waveform down on the screen, press the bottom of the channel 1 position button.

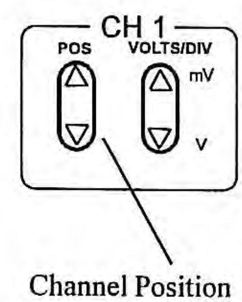
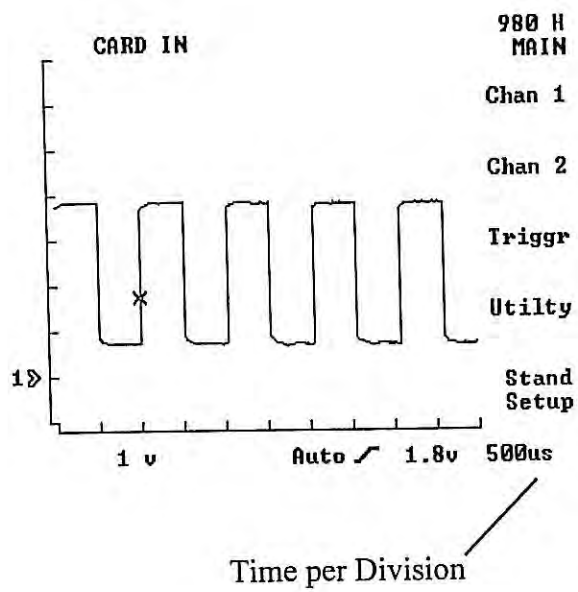


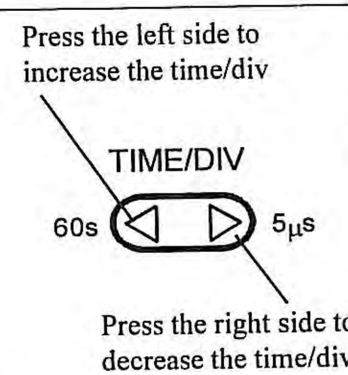
Figure 4-P: Changing Volts/Div and Position



Changing Time per Division

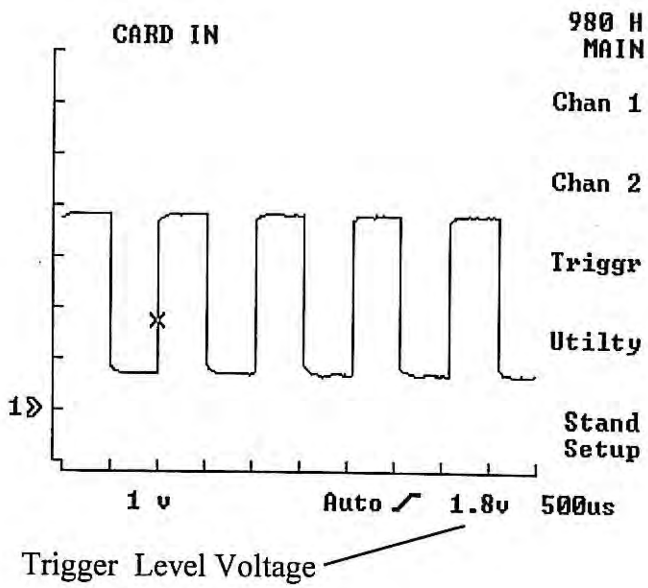
Follow these steps to change the time per division, using a live, repetitive waveform:

1. To increase the time/div press the left side of the time/div button.
2. To decrease the time/div press the right side of the time/div button.



(Note: Increasing the time per division will appear to compress the displayed waveform on the screen, decreasing the time per division will appear to expand the displayed waveform on the screen.)

Figure 4-Q: Changing Time/Div

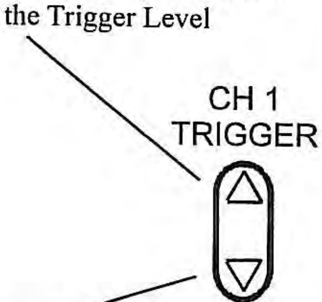


Changing the Trigger

Follow these steps to change the trigger level, using a live, repetitive waveform:

1. To increase the trigger level, press the top of the trigger level button.
2. To decrease the trigger level, press the bottom of the trigger level button.

Press the top to increase the Trigger Level



Press the bottom to decrease the Trigger Level

Figure 4-R: Changing Trigger Level

Chapter 5 - Automotive Diagnostics & Applications

How and where you hook up to sensors and signals in the vehicle is important. You should never pierce any wire insulation, strip insulation away or break a weather pack seal. The best way to view vehicle signals is to use a recommended or approved breakout box. The next best approach is to use an old wiring harness to make your own breakout leads. Once you have made a good connection, it is important to check that all leads and cables are away from hot surfaces, belts, fans, moving parts and secondary ignition wires. Remember that connections can move around after the engine is started. A poor signal or one that disappears, could be bad due to a poor connection.

It is important that you only use probes that are recommended as an option or supplied with your lab scope. Using probes that are not recommended for use could seriously distort the measurement you are making and may even damage the lab scope or the circuit or sensor that is connected. When probing certain sensors, like an O_2 sensor, you should never short the output of the O_2 sensor or load them down.

In this next section we will explore a number of common waveform shapes from various vehicle manufacturers with oscilloscope set-ups. These waveforms represent typical signals from actual automotive outputs.

Signals that you acquire from similar vehicles may appear different. These waveform shapes and oscilloscope set-ups will give you a quick working knowledge of how to set-up your lab scope for various automotive signal types you will encounter.

The good news is that all of these waveforms and front panel control settings are pre-programmed into the memory card on the lab scope. This makes the lab scope extremely easy to use for diagnosing the most common driveability problems.

On the following pages you will find an easy to follow format for using these pre-programmed waveforms.

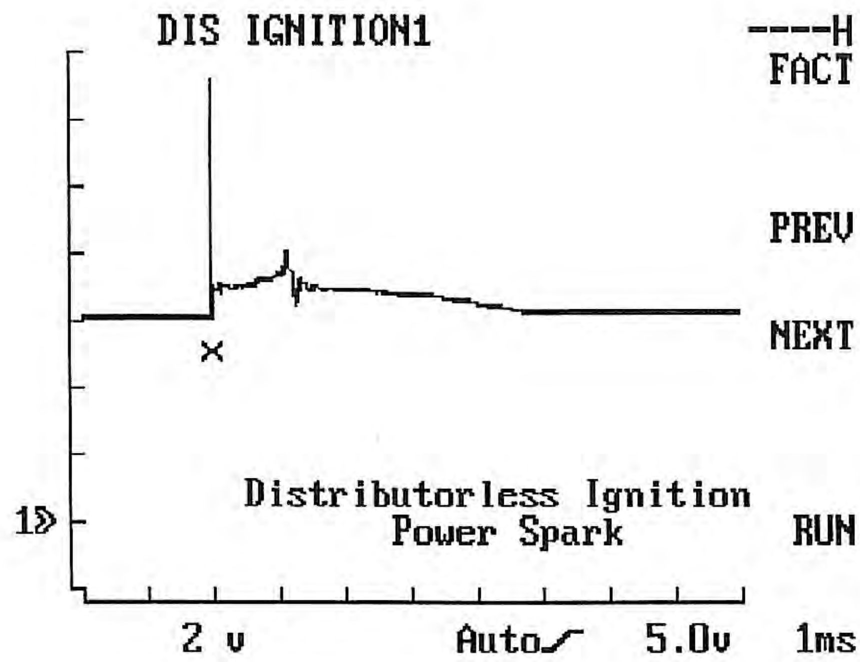


Figure 5-A: DIS Power Spark

Testing a Distributorless Ignition Output

1. Turn on the lab scope.
2. Connect the capacitive probe to the channel 1 and common inputs.
3. Connect the capacitive probe around the output of any coil pack.
4. Connect the Black test lead to a good ground on the engine.
5. Press the Recall Card button on the lab scope.
6. Scroll through the stored waveforms by pressing the Next button until you find the DIS IGNITION1 waveform.
7. Press the Run button and the lab scope is ready to start displaying a signal.
8. Start the engine and observe the display.

*(**Note:** You may need to reverse the black and red test leads at the labscope or adjust the trigger level again. A 1 volt signal on the scope represents 4,000 volts at the coil.)*

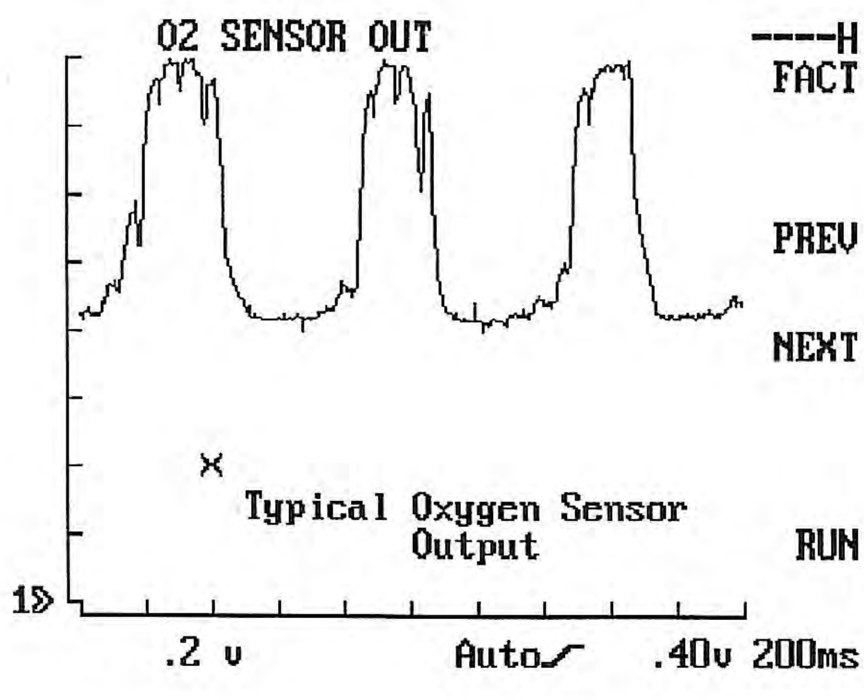


Figure 5-B: O_2 Sensor Output

Testing an O_2 Sensor Output

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the O_2 Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the O2 SENSOR OUT waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and let it warm up. The O_2 sensor must be warm to operate properly, then, observe the display.

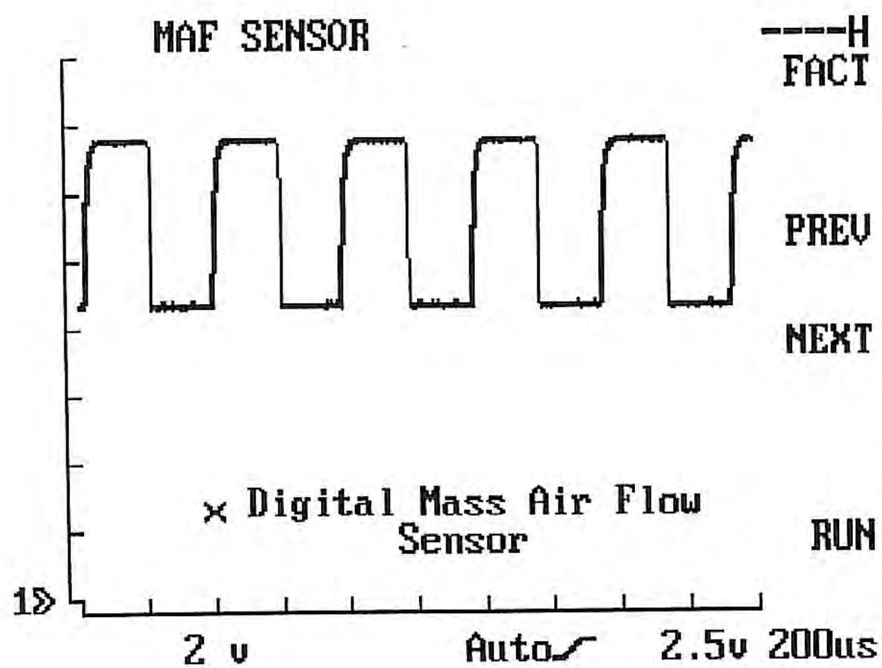


Figure 5-C: Digital Mass Air Flow Sensor

Testing a Digital Mass Air Flow Sensor

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Mass Air Flow Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the MAF SENSOR waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

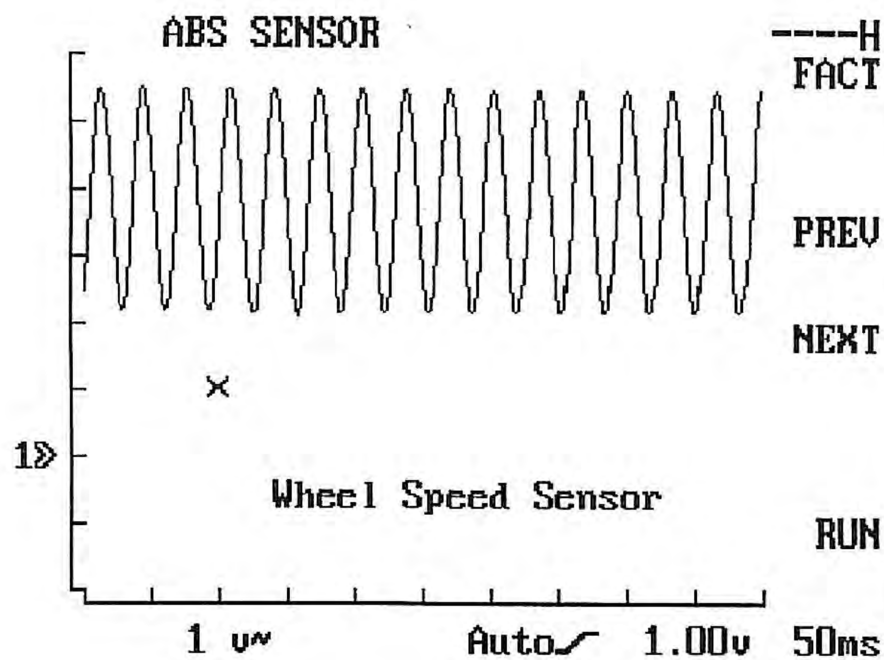


Figure 5-D: ABS Wheel Speed Sensor

Testing a Wheel Speed Sensor

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red and Black test leads to the output of the Wheel Speed Sensor.
5. Press the Recall Card button on the lab scope.
6. Scroll through the stored waveforms by pressing the Next button until you find the ABS SENSOR waveform.
7. Press the Run button and the lab scope is ready to start displaying a signal.

*(**Note:** You can road test the vehicle with someone else driving while you observe the scope display, or you can put the vehicle up on a floor jack and spin the front wheel by hand.)*

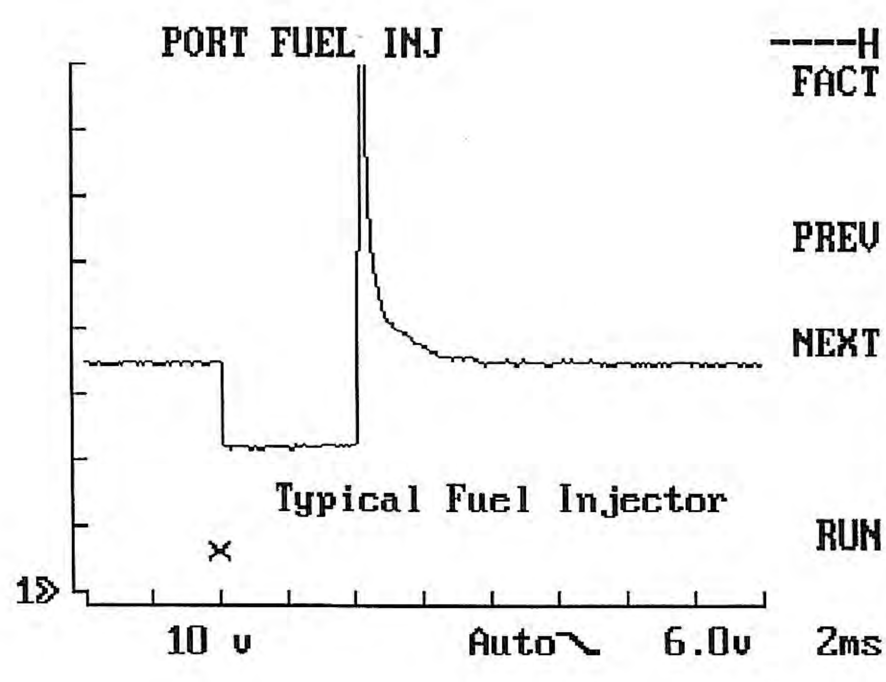


Figure 5-E: Port Fuel Injector

Testing a Port Fuel Injector

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Port Fuel Injector.
5. Connect the Black test lead to a good ground, close to the injector.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the PORT FUEL INJ waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

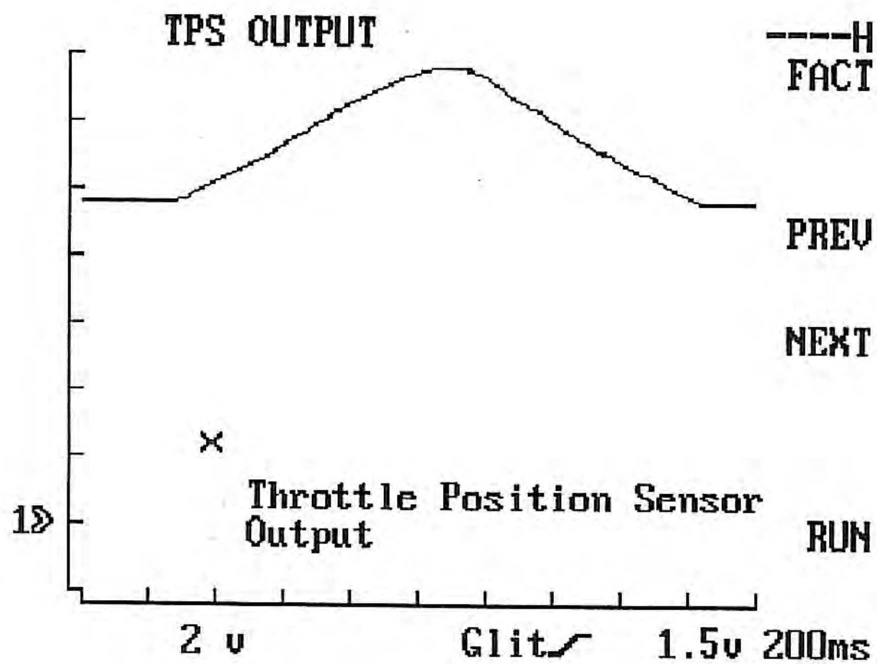


Figure 5-F: Throttle Position Sensor

Testing a Throttle Position Sensor

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Throttle Position Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the TPS OUTPUT waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Do not start the engine, turn the key on.
10. Rotate the throttle open and closed and observe the display.

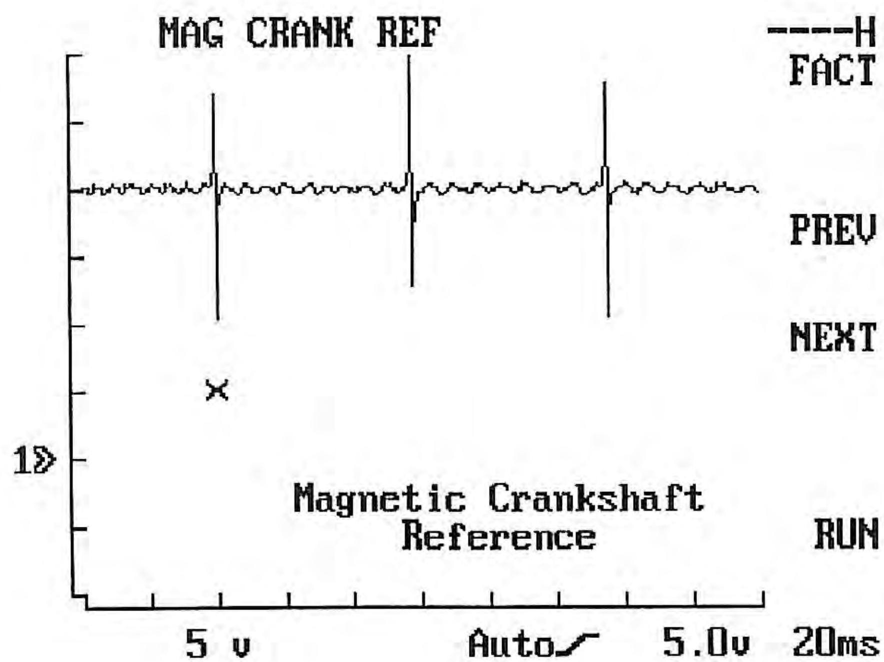


Figure 5-G: Magnetic Crankshaft Reference

Testing a Magnetic Crank Reference

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Magnetic Crank Reference Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the MAG CRANK REF waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

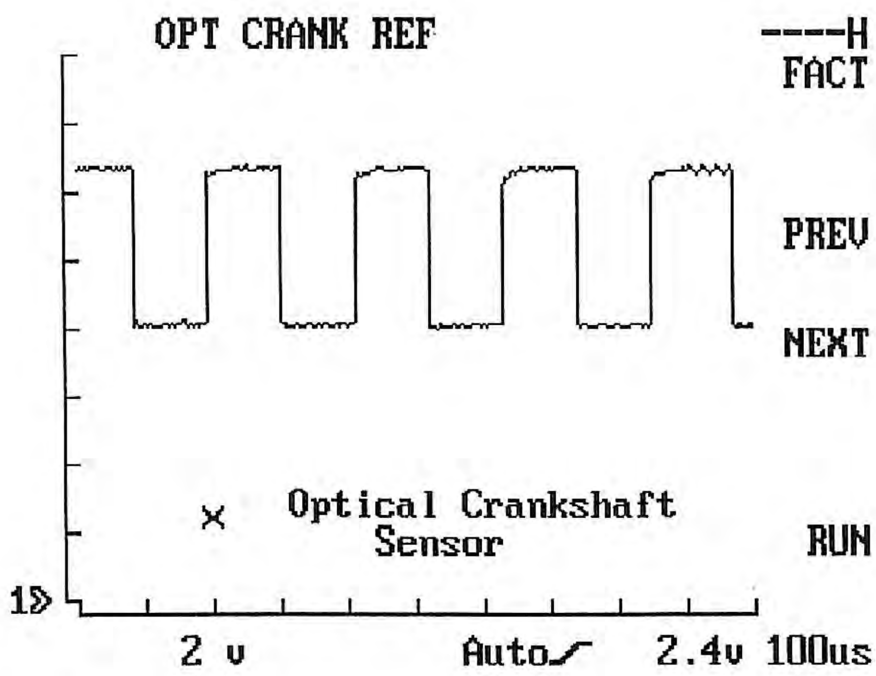


Figure 5-H: Optical Crankshaft Reference

Testing an Optical Crank Sensor

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Optical Crank Reference Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the OPT CRANK REF waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

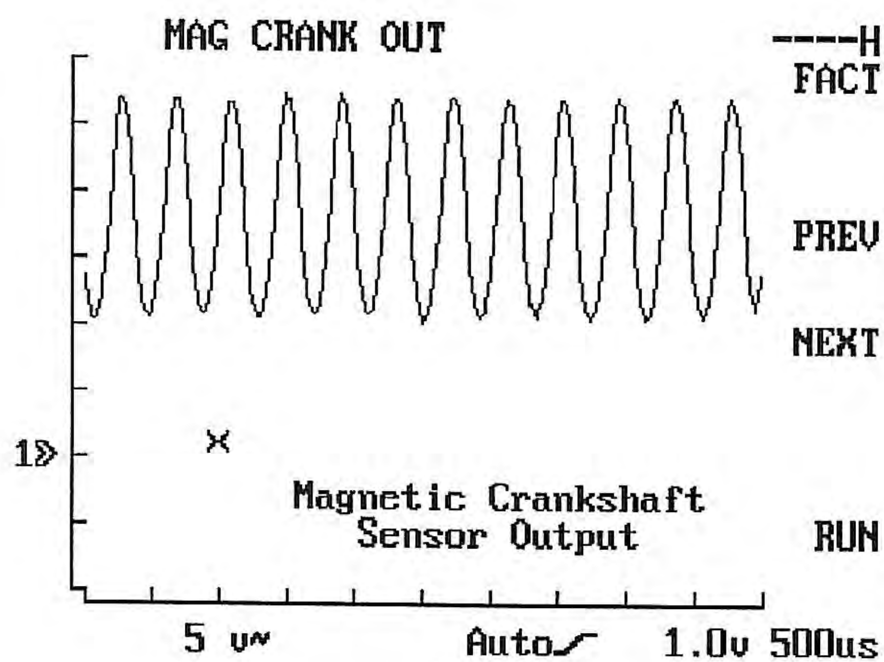


Figure 5-I: Magnetic Crankshaft Sensor

Testing a Magnetic Crankshaft Sensor

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red and Black test leads to the output of the Magnetic Crank Sensor.
5. Press the Recall Card button on the lab scope.
6. Scroll through the stored waveforms by pressing the Next button until you find the MAG CRANK OUT waveform.
7. Press the Run button and the lab scope is ready to start displaying a signal.
8. Start the engine and observe the display.

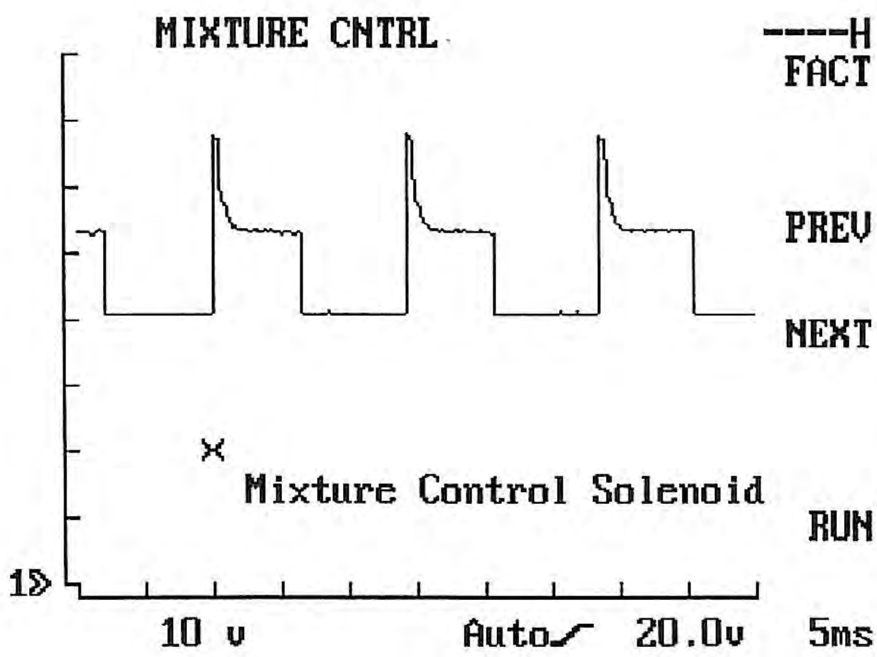


Figure 5-J: Mixture Control Solenoid

Testing the Mixture Control Solenoid

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Mixture Control Solenoid.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the MIXTURE CNTRL waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

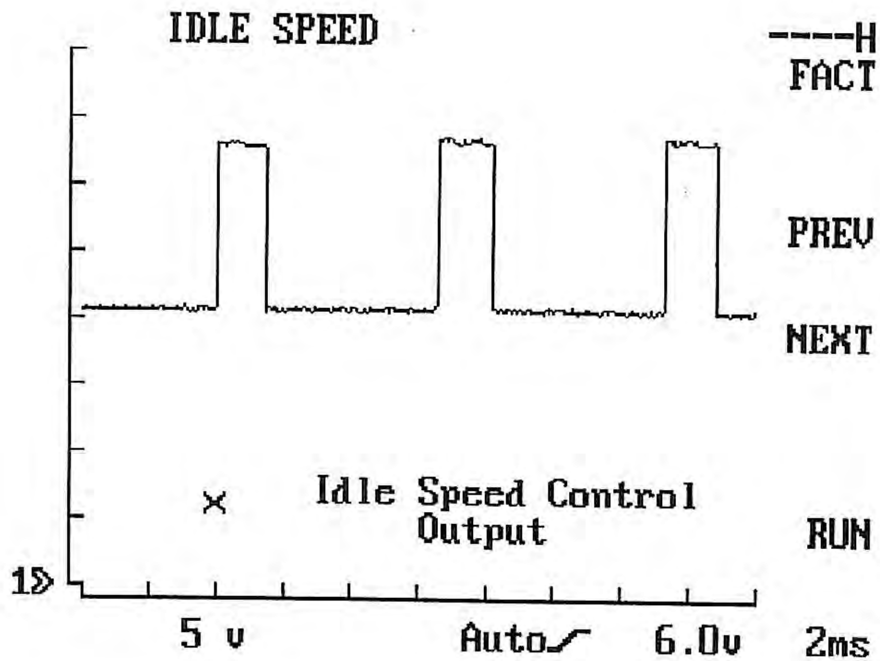


Figure 5-K: Idle Speed Control

Testing an Idle Speed Control Output

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Idle Speed Control.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the IDLE SPEED waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

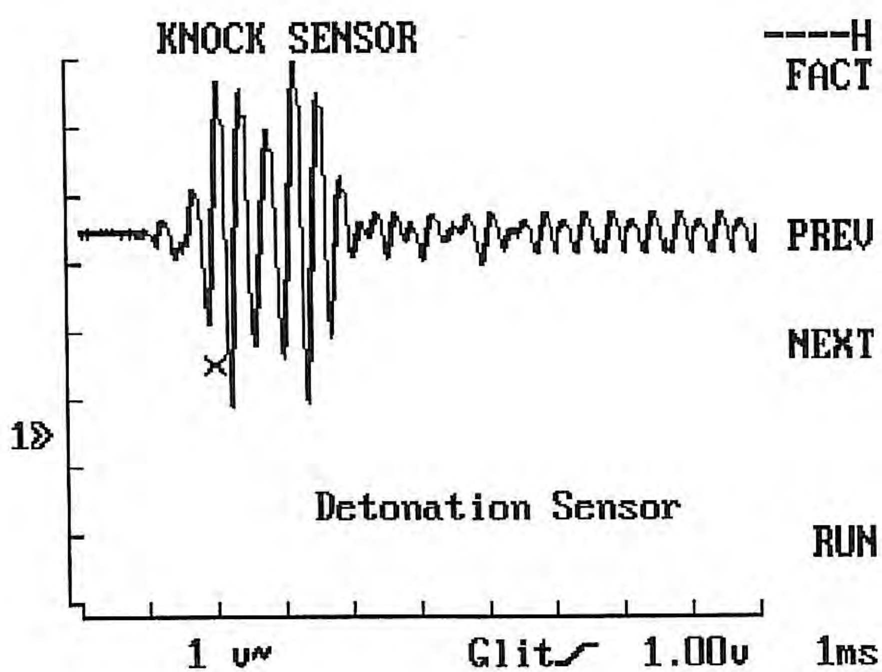


Figure 5-L: Knock Sensor

Testing a Knock Sensor Output

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Knock Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the KNOCK SENSOR waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Gently tap the engine with a tool near the sensor and observe the display.

(Note: The engine should not be running while you observe the scope display.)

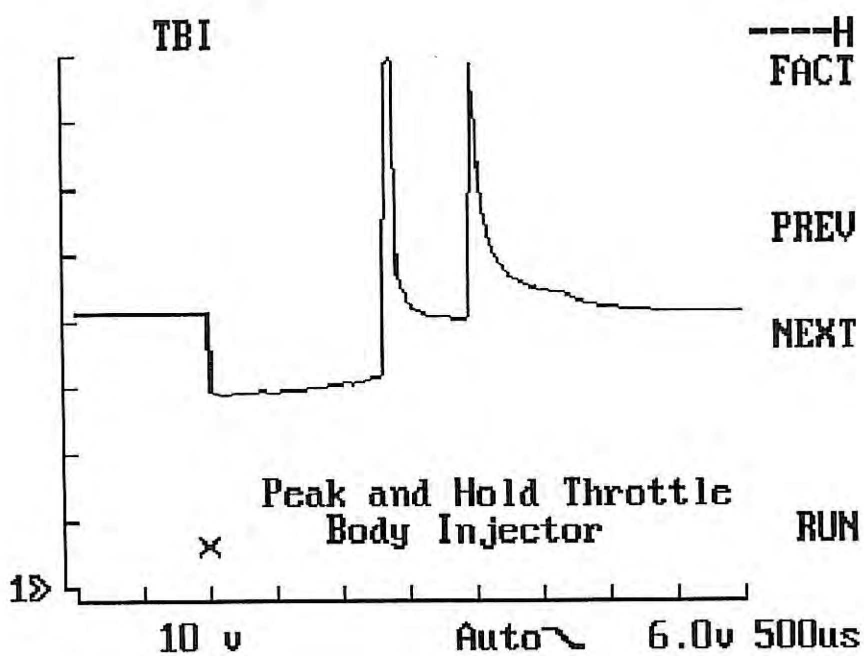


Figure 5-M: Throttle Body Injector

Testing a Throttle Body Injector

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the TBI.
5. Connect the Black test lead to a good ground, close to the injector.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the TBI waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

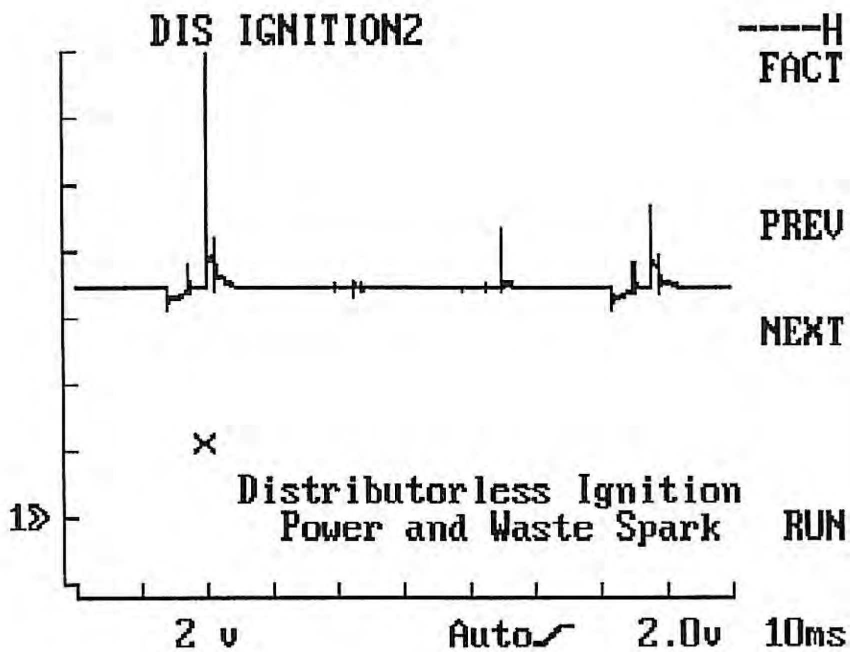


Figure 5-N: DIS Power and Waste Spark

Testing a Distributorless Ignition Output

1. Turn on the lab scope.
2. Connect the capacitive probe to the channel 1 and common inputs.
3. Connect the capacitive probe around the output of any coil pack.
4. Connect the Black test lead to a good ground on the engine.
5. Press the Recall Card button on the lab scope.
6. Scroll through the stored waveforms by pressing the Next button until you find the DIS IGNITION2 waveform.
7. Press the Run button and the lab scope is ready to start displaying a signal.
8. Start the engine and observe the display.

(Note: You may need to reverse the black and red test leads at the labscope or adjust the trigger level again. A 1 volt signal on the scope represents 4,000 volts at the coil.)

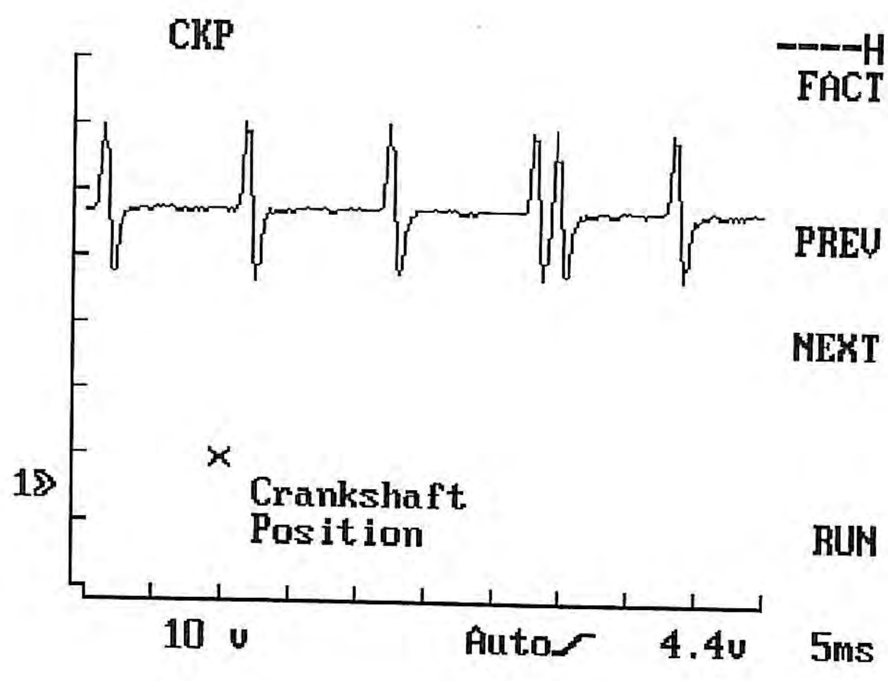


Figure 5-O: Crankshaft Position Sensor

Testing a Crankshaft Position Sensor

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Crankshaft Position Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the CKP waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

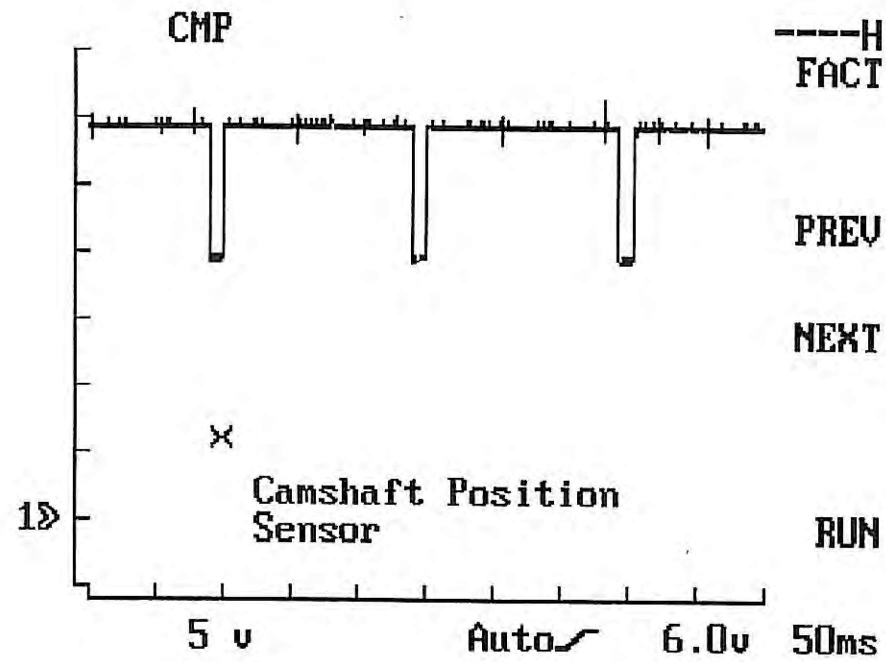


Figure 5-P: Camshaft Position Sensor

Testing a Camshaft Position Sensor

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Cam Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the CMP waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

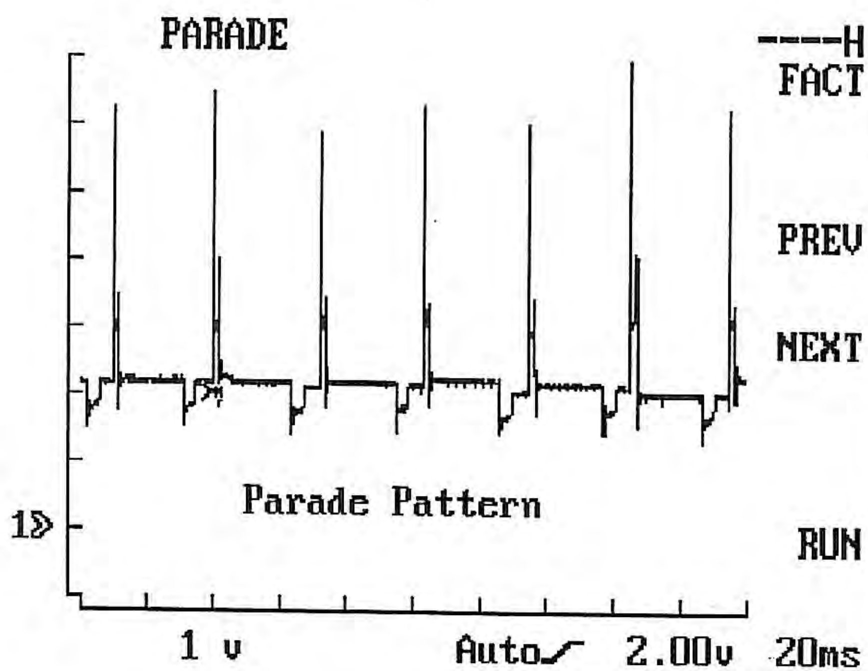


Figure 5-Q: Coil Output Parade Pattern

Testing an Ignition Coil Output for a Parade Pattern

1. Turn on the lab scope.
2. Connect the capacitive probe to the channel 1 and common inputs.
3. Connect the capacitive probe around the output of the coil.
4. Connect the Black test lead to a good ground on the engine.
5. Press the Recall Card button on the lab scope.
6. Scroll through the stored waveforms by pressing the Next button until you find the PARADE waveform.
7. Press the Run button and the lab scope is ready to start displaying a signal.
8. Start the engine and observe the display.

(Note: You may need to reverse the black and red test leads at the labscope or adjust the trigger level again. A 1 volt signal on the scope represents 4,000 volts at the coil.)

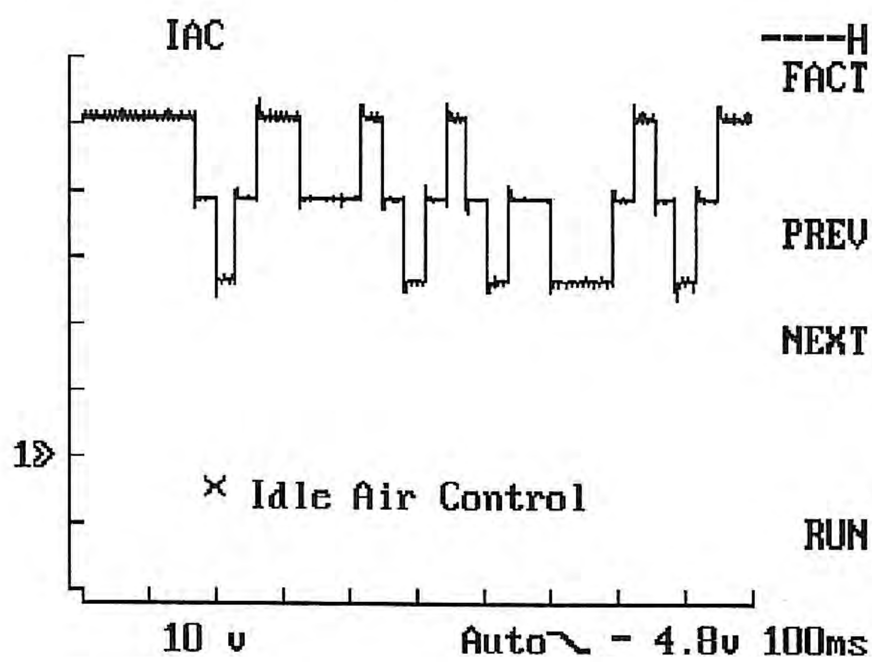


Figure 5-R: Idle Air Control Motor

Testing the Idle Air Control Motor Input

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to one high side input of the Idle Air Control Motor.
5. Connect the Black test lead to the other high side input of the Idle Air Control Motor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the IAC waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine, snap the throttle gently and observe the display.

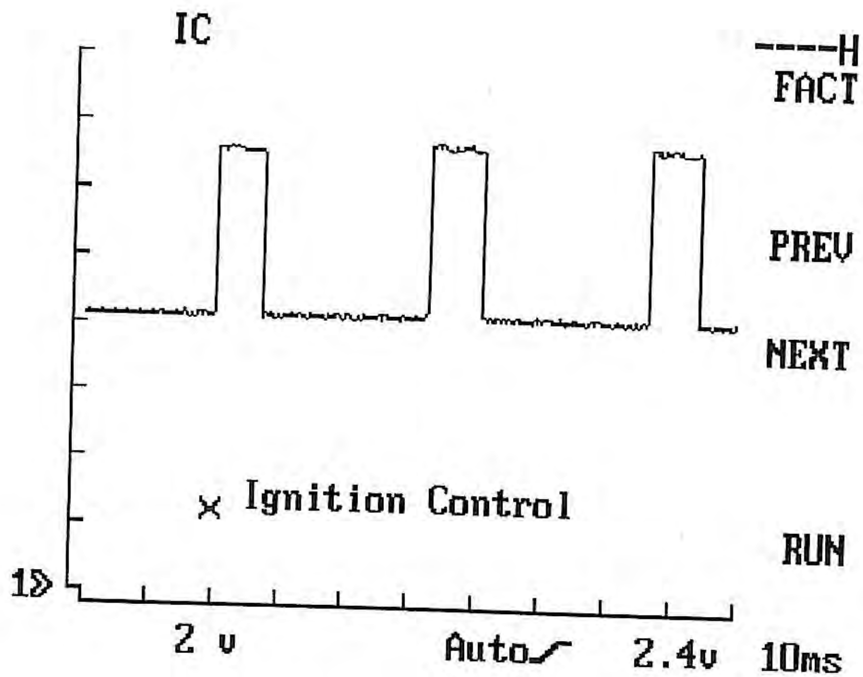


Figure 5-S: Ignition Control Signal

Testing an Ignition Control Signal

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Ignition Control Signal.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the IC waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine and observe the display.

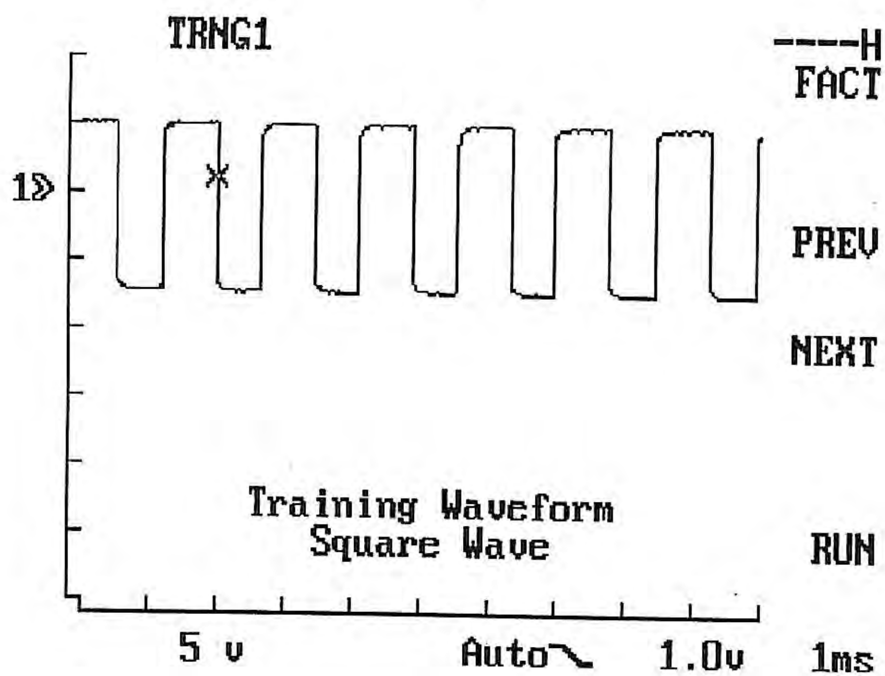


Figure 5-T: Training Waveform - Square Wave

Testing the Training Waveform

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the Square Wave output, TP2 on the Signal Generator.
5. Connect the Black test lead to ground, TP7 on the Signal Generator.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the TRNG1 waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Turn on the Automotive Signal Generator and observe the display.

*(**Note:** To perform this test requires the use of the optional Automotive Signal Generator.)*

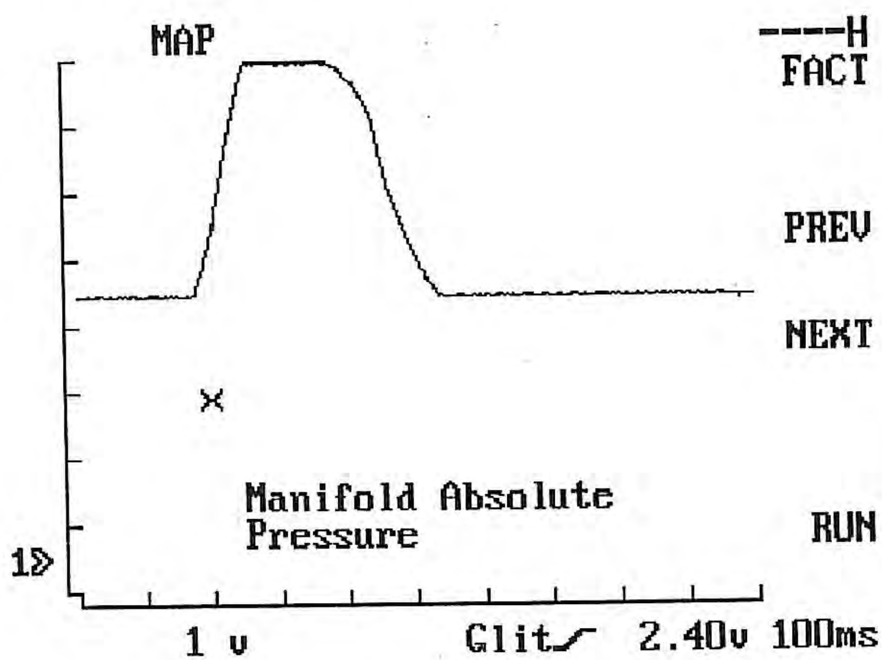


Figure 5-U: Manifold Absolute Pressure Sensor

Testing an Analog MAP Sensor

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the MAP Sensor.
5. Connect the Black test lead to a good ground, close to the sensor.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the MAP output waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Start the engine.
10. Gently snap the throttle open and closed and observe the display.

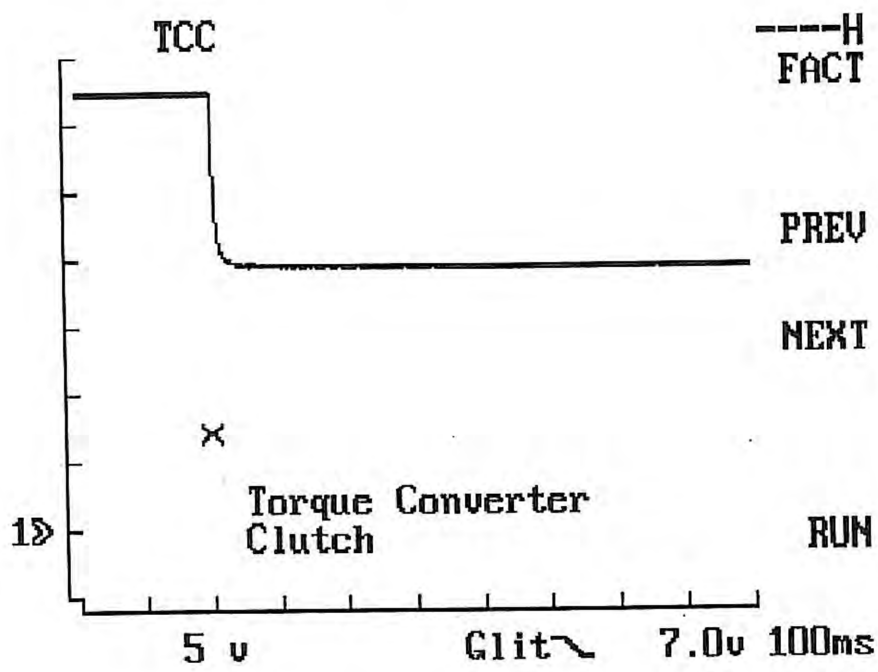


Figure 5-V: Torque Converter Clutch Switch

Testing a Torque Converter Clutch Switch

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the output of the Torque Converter Clutch Switch.
4. Connect the Black test lead to a ground near the torque converter clutch switch.
5. Press the Recall Card button on the lab scope.
6. Scroll through the stored waveforms by pressing the Next button until you find the TCC waveform.
7. Press the Run button and the lab scope is ready to start displaying a signal.

(Note: You can road test the vehicle with someone else driving while you observe the scope display.)

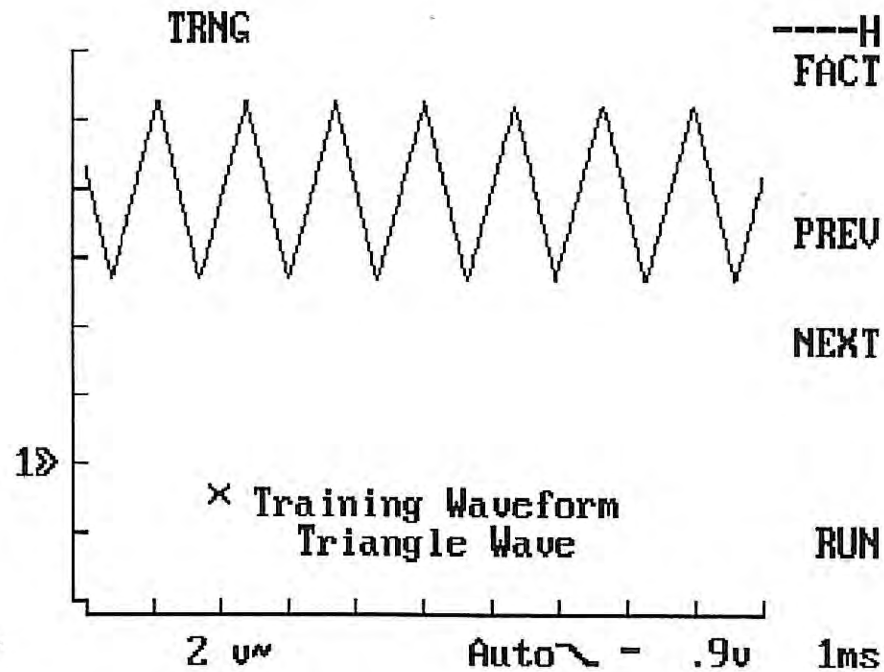


Figure 5-W: Training Waveform - Triangle Wave

Testing the Training Waveform

1. Turn on the lab scope.
2. Connect the Red test lead to the channel 1 input.
3. Connect the Black test lead to the common input.
4. Connect the Red test lead to the Square Wave output, TP3 on the Signal Generator.
5. Connect the Black test lead to ground, TP7 on theAutomotive Signal Generator.
6. Press the Recall Card button on the lab scope.
7. Scroll through the stored waveforms by pressing the Next button until you find the TRNG waveform.
8. Press the Run button and the lab scope is ready to start displaying a signal.
9. Turn on the Signal Generator and observe the display.

*(**Note:** To perform this test requires the use of the optional Automotive Signal Generator.)*

Specifications for the ADL 7100

Vertical Deflection

Sampling Rate	*5 megasamples/second*
Bandwidth	*DC: DC to 500 kHz* *AC: 10 Hz to 500 kHz*
Resolution	*8 bits*
Deflection	*50 mV/Div to 10 V/Div (in a 1, 2, 5 sequence)*
Input Impedance	*10 MΩ ± 2%, 25 pf ± 5%*
Accuracy	*± 5%*
Coupling	*DC (default), AC*
Maximum Input Voltage	*500 V (DC + AC P-P)*
Input Surge Protection	*30 KV*

Horizontal Deflection

Resolution	*8 Bits, 320 Pixels*
Sweep Rate	*5 µS/div to 60 S/div (in a 1, 2, 5 sequence) Scan Mode below 100 mS/div*

Trigger System

Triggering Mode	*Auto DC (50% point) with selectable AC, Normal and Single*
Pre-Trigger Mode	*Fixed at 2 divisions (20%)*
Source	*Internal only, Channel 1*
Slope	*+ or - (default to +)*

Acquisition

Mode	*Min/Max*
Frequency	*4 digit resolution to 500 kHz*

Interface

Format	*RS232C, Talk/Listen with optional adaptor*

Display

Total Area	*LCD 240 X 320 Matrix*

Memory	
Capacity	*4 Waveforms at 250 points each*
Format	*Plug-in Card*
Content	*Each card contains up to 31 waveforms, character descriptions and oscilloscope settings*
Operation	*Scroll through*
Power	
Internal Source	*Lead acid sealed battery*
External Source	*9 volt DC, 500 mA*

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Glossary

AC (<u>A</u>lternating <u>C</u>urrent)
A signal in which the current and voltage vary in a repeating pattern over time.

ADC (<u>A</u>nalog-to-<u>D</u>igital <u>C</u>onverter)
A digital electronic component that converts an electrical signal into discrete binary values.

Aliasing
Aliasing occurs when a digital oscilloscope does not take enough samples on a particular signal. After the oscilloscope reconstructs and displays the waveform you can be "fooled" into seeing a false waveform. The ADL 7100 uses Min/Max acquisition at all sweep speeds, this prevents the scope from aliasing a waveform.

Amplitude
The magnitude of a quantity or strength of a signal. In electronics, amplitude usually refers to either voltage or current.

Attenuation
A decrease in signal voltage during its transmission from one point to another.

Averaging
A processing technique used by digital oscilloscopes to minimize noise in a signal.

Bandwidth
A frequency range.

CRT (<u>C</u>athode-<u>R</u>ay <u>T</u>ube)
An electron-beam tube in which the beam can be focused on a luminescent screen and varied in both position and intensity to produce a visible pattern. A television picture tube is a CRT.

Circuit Loading
The unintentional interaction of the probe and oscilloscope with the circuit being tested, distorting the signal.

Coupling
The method of connecting two circuits together. Circuits connected with a wire are directly coupled; circuits connected through a capacitor or a transformer are indirectly (or AC) coupled.

DC (Direct Current)
A signal with a constant voltage and current.

Display
The surface of the oscilloscope upon which the visible pattern is produced in the display area.

Division
Measurement markings on the display graticule of the oscilloscope.

Earth Ground
A conductor that will dissipate large electrical currents into the Earth.

Focus
The oscilloscope control that adjusts the CRT electron beams to control the sharpness of the display.

Frequency
The number of times a signal repeats in one second, measured in Hertz (cycles per second). The frequency equals 1/period.

Glitch
An intermittent error in a circuit.

Graticule
The grid lines on a display for measuring oscilloscope traces.

Ground
1. A conducting connection by which an electric circuit or equipment is connected to the earth to establish and maintain a reference voltage level.

2. The voltage reference point in a circuit.

Hertz (Hz)
One cycle per second; the unit of frequency.

Kilohertz (kHz)
1000 Hertz; a unit of frequency.

Megahertz (MHz)
1,000,000 Hertz; a unit of frequency.

Megasamples per second (MS/s)
A sample rate unit equal to 1,000,000 samples every second.

Microsecond (μs)
A unit of time equivalent to 0.000001 seconds.

Millisecond (ms)
A unit of time equivalent to 0.001 seconds.

Noise
An unwanted voltage or current in an electrical circuit.

Oscilloscope
An instrument used to make voltage changes visible over time. The word oscilloscope comes from "oscillate," since oscilloscopes are often used to measure oscillating voltages.

Peak (Vp)
The maximum voltage level measured from a zero reference point.

Peak-to-peak (Vp-p)
The voltage measured from the maximum point of a signal to its minimum point, usually twice the Vp level.

Period
The amount of time it takes a wave to complete one cycle. The period equals 1/frequency.

Phase
The amount of time that passes from the beginning of a cycle to the beginning of the next cycle, measured in degrees. One complete cycle represents 360°.

Probe
An oscilloscope input device, usually having a pointed metal tip for making electrical contact with a circuit element and a flexible cable for transmitting the signal to the oscilloscope.

Pulse
A common waveform shape that has a fast rising edge, a width, and a fast falling edge.

RMS (Root Mean Square)
For a sine wave, RMS is the peak voltage multiplied by 0.707 this gives the equivalent DC voltage value that would be required to produce the same amount of power through a fixed resistor.

Real-time Sampling
A sampling mode in which the oscilloscope collects as many samples as it can as the signal occurs.

Record Length
The number of waveform points used to create a record of a signal.

Rise Time
The time taken for the leading edge of a pulse to rise from its minimum to its maximum values (typically measured from 10% to 90% of these values).

Sample Point
The raw data from an ADC used to calculate waveform points.

Screen
The surface of the oscilloscope upon which the visible pattern is produced in the display area.

Signal Generator
A test device for injecting a signal into a circuit input; the circuit's output is then read by an oscilloscope.

Sine Wave
A common curved wave shape that is mathematically defined.

Single Shot
A signal measured by an oscilloscope that only occurs once (also called a transient event).

Slope
On an oscilloscope display, the ratio of a vertical distance to a horizontal distance. A positive slope increases from left to right, while a negative slope decreases from left to right.

Square Wave
A common wave shape consisting of repeating square pulses.

Sweep
One horizontal pass of an oscilloscope's trace from left to right across the display.

Sweep Speed
Same as the time base.

Time Base
Oscilloscope circuitry that controls the timing of the sweep. The time base is set by the seconds/division control.

Trace
The visible shapes drawn on an oscilloscope display.

Transducer
A device that converts a specific physical quantity such as sound, pressure or light intensity into an electrical signal.

Transient
A signal measured by an oscilloscope that only occurs once (also called a single-shot event).

Trigger
The circuit that initiates a horizontal sweep on an oscilloscope and determines the beginning point of the waveform.

Trigger Level
The voltage level that a trigger source signal must reach before the trigger circuit initiates a sweep.

Volt
The unit of electric potential difference.

Voltage
The difference in electric potential, expressed in volts, between two points.

Waveform
A graphic representation of a voltage varying over time.

Waveform Point
A digital value that represents the voltage of a signal at a specific point in time. Waveform points are calculated from sample points and stored in memory.

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